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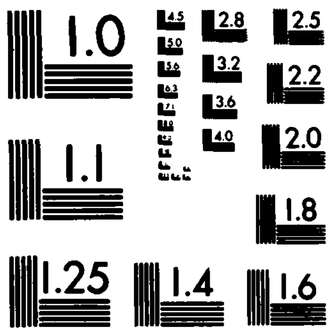
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TECHNICAL REPORT: NAVTRAEQUIPCEN 77-C-0110-1

COMPUTER BASED LANDING SIGNAL OFFICER CARRIER AIRCRAFT RECOVERY MODEL

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September 1983

FINAL REPORT FOR PERIOD OCTOBER 1977-JULY 1980

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This report describes a two phase research effort to develop a two phase Landing Signal Officer (LSO) decision-making model to serve as a performance criterion in an automated training system. In the first of the two-phase development effort, analytic methods including observations, interviews, conferences and literature reviews were used to collect data concerning the LSO functions and decision-making processes during carrier aircraft recovery operations.

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Two hundred and fifty Field Carrier Landing Practice approaches during day and night operations were observed at NAS Point Mugu, California, and approximately 700 landings and approaches were observed during day and night carrier qualification training and airwing training operations on the USS ENTERPRISE (CV-65) and USS CORAL SEA (CV-43), respectively.

The resulting LSO model represents the decision-making of the LSO in terms of voice call selection and wave-offs during carrier approach and consists of a set of decision rules relating A-7 aircraft dynamics to LSO calls. The model is represented in two formats: Flowchart and Call-Listing.

Since model development was based on observations and interviews of LSOs, estimates of the aircraft approach parameters are of undetermined accuracy. Efforts of the second phase were directed toward determining accurate measures of the aircraft approach dynamics and corresponding LSO voice calls. The objective was to develop a quantified, probabilistic model of LSO decision-making during carrier approach. However, LSO model quantification was not possible due to difficulties and delays associated with data collection and reduction.

Reduction and analysis of the data will be completed and the result will be published in a later report.

PREFACE

The authors would like to express their appreciation for the support, encouragement, and assistance of the following:

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Special thanks are extended to the LSOs of Squadron VA-122, NAS Lemoore, for their participation throughout the study.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

SECTION I

INTRODUCTION

This report describes the work accomplished by Human Performance Research, Inc. (HPR) during the first phase of a two-phase study entitled Computer Based Landing Signal Officer Carrier Aircraft Recovery Model. In the first phase, the decision-making processes of the Landing Signal Officer (LSO) were modeled through analytic techniques. In the second phase, empirical data were collected in an attempt to relate aircraft approach measures to LSO control actions. Reduction of second phase data has been delayed by resource limitations and will be published in a follow-on report when results become available.

The ultimate goal of the study is to enhance the safety and efficiency of carrier aircraft recovery operations by contributing to the development of an LSO training system. Through radio transmissions to the pilot, the LSO controls aircraft during the final approach and landing phases of carrier recovery operations. Therefore, the proficiency with which he executes his job can have a direct effect on carrier landing accident rate and the efficiency of recovery operations.

The LSO's job is complex and demanding. This is indicated by the time required to qualify as an LSO: approximately 15 months for initial qualification to control a single type of aircraft; and approximately two additional years to control all types of carrier aircraft (Borden, 1969).

Despite the complexity and importance of the LSO's job, LSO training has remained essentially the same since LSOs were first introduced into carrier aviation. No other aspect of carrier aviation training has remained as unchanged as LSO training, and received so little attention from training specialists. Yet, with the possible exception of landing aboard carriers, no other task is more demanding or complex.

This study was part of a NAVTRAEQUIPCEN program to develop an automated training system for LSOs. This part of the program was directed toward a systematic definition of the LSO's task in a form that could be translated into software for use in automated performance measurement and evaluation.

Before defining the study tasks and procedures more explicitly, a brief description of carrier aircraft operations and the role of the LSO will be given.

CARRIER AIRCRAFT OPERATIONS

Carrier aircraft operations are performed to accomplish two separate missions--an antisubmarine warfare (ASW) mission and a tactical air (TACAIR) mission. Until several years ago, these missions were performed independently by two different classes of carriers--the CVA and CVS. Today, the missions are performed by a single class of carrier--the CV. The consolidation of these missions has significantly increased the amount of flight operations and the burden placed upon carrier personnel.

In combat, carrier aircraft operations may be performed continuously throughout each 24-hour period. During peacetime, aircraft operations are rarely performed continuously over a 24-hour period; the ASW mission is performed for the entire 24-hour period, and the TACAIR mission is performed for a 12-hour segment of the period.

During a 24-hour operational period, 130 to 150 sorties will be flown. Sorties are launched and recovered in groups, referred to as events. Events are launched and recovered in cycles. The cyclic interval between launches and recoveries varies: during the 12-hour combined TACAIR/ASW period, the cyclic interval is 1 hour and 45 minutes; during the 12-hour ASW period, the cyclic interval is 4 hours. Cyclic intervals will vary somewhat between and within carriers.

At each cyclic interval, as many as 30 to 40 aircraft will launch and recover--15 to 20 aircraft in the launching event followed immediately by recovery of 15 to 20 aircraft from the preceding event. This tempo would be impressive on a land-based air station; it is formidable when conducted from the limited confines of a pitching carrier deck, at any hour of the day or night, and during all weather conditions.

THE ROLE OF THE LSO IN CARRIER AIRCRAFT OPERATIONS

The LSO is responsible for the safe and expeditious recovery of carrier aircraft. This task has been made more difficult by the increased complexity and tempo of carrier operations.

The term "paddles" is still used today to refer to the LSO despite the fact that it has been 25 years since LSOs have used paddles to communicate signals to pilots of approaching aircraft. In 1955, visual landing aids and voice communications were introduced to allow jet aircraft to fly a constant glideslope approach, rather than the flat approach followed by a power "cut" that was practiced by earlier pilots (see Borden, 1969).

The LSO still monitors the approach from the LSO platform at the edge of the flight deck. However, he no longer "signals" the pilot. He communicates verbally, via radio, while the pilot monitors the Fresnel Lens Optical Landing System (FLOLS) for glideslope information. The FLOLS is located adjacent to the landing area and consists of vertically oriented cells (called "balls") and a set of horizontal datum lights intersecting the center cell. If the pilot is above or below glideslope, the "ball" appears above or below the horizontal datum lights. This constitutes a form of manual control system where the pilot attempts to maintain a centered ball through compensatory tracking, primarily by the use of power (thrust) adjustments, and secondarily, through elevator adjustments (fore and aft joystick movements).

Horizontal approach errors, called lineup errors, are controlled almost entirely with angle-of-bank by side-to-side movement of the stick. The pilot's visual reference for lineup is the centerline of the carrier's angle deck. The angle deck is oriented ten degrees counterclockwise from the longitudinal axis of the carrier. As a result, the carrier is continually moving slightly to the right of the approaching aircraft. This movement induces lineup deviations by causing the aircraft to drift to the left of centerline. Aircraft drift additionally can be affected by relative wind direction which may be as much as ten degrees to the right of the aircraft, due to the forward movement of the carrier.

The LSO controls the aircraft from approximately three-quarters of a mile until an arrested landing ("trap") occurs, when the aircraft's hook engages one of the four cross-deck pendants, or "wires." A "bolter" occurs when the aircraft lands but the hook touches down beyond the last (No. 4) wire, or skips over the wires ("hook-skip bolter"). Not all approaches result in a trap or bolter. A missed approach can occur when the aircraft is waved-off by either the LSO or Air Officer. The pilot also can initiate a wave-off. The majority of wave-offs are initiated by the LSO because of poor pilot techniques or because preparations were not completed on the flight deck to land the aircraft. For example, the pendant engaged by the previous aircraft may not have been completely retracted by the time the next aircraft is ready to land. A wave-off for incompleted preparation is termed a "foul deck wave-off," as opposed to a wave-off for poor pilot technique, termed a "technique wave-off." The pilot executes a wave-off by adding full military power and rotating the nose of the aircraft to a pitch attitude that will quickly establish a positive rate of climb.

Carrier landing accidents can be categorized into two common types--the undershoot (ramp strike) and the hard landing. Ramp strikes occur when the aircraft strikes the ramp, or round down, of the carrier. Hard landings occur when the aircraft contacts the flight deck at an excessive rate of descent (sink rate). A hard landing also can occur when the aircraft engages a pendant while executing a wave-off. This is called an in-flight engagement (IFE). Ramp strikes are the most serious accidents in carrier aviation and typically result in major damage to the aircraft and pilot injury or loss of life.

Ramp strikes and in-flight engagements comprise ninety-three percent of carrier landing accidents (Brictson, 1970). Data obtained in the present study indicate that, of the landing accidents from 1970-1977 in which the LSO was cited as a causal or contributing factor, ninety percent were either ramp strikes or hard landings. Also, thirty-eight percent of the hard landings in which the LSO was cited during this period resulted from in-flight engagements. Unfortunately, no statistics can be accumulated to reveal how many accidents are prevented by timely LSO action. One estimate of LSO effectiveness, reported by Durand and Wasicko (1967), was that ninety percent of the approaches that would result in a landing accident are prevented by LSOs' wave-offs.

The fundamental responsibility of the LSO is to enhance the safety of the carrier landing process. Through corrective assistance, he helps the pilot to fly a safer approach. Assistance is provided by informative and precautionary calls that provide the pilot with information about his position, and quickly direct the pilot's attention to potential difficulties. Imperative calls are used by the LSO when a mandatory, immediate response is required from the pilot. Imperative calls shift a degree of the responsibility of decision and control from the pilot to the LSO. Seconds before the aircraft crosses the ramp, a final critical decision is made by the LSO--can the aircraft continue safely, or should the approach be terminated? The LSO terminates the approach by commanding a wave-off whenever he judges it necessary for safety.

The role of the LSO is described in the LSO NATOPS Manual, in part, as follows:

> The Landing Signal Officer's primary responsibility is the safe and expeditious recovery of aircraft aboard ship. The employment of high performance aircraft and the necessity for all weather operations have placed ever increasing demands on the LSO's skill and judgement. Through training and experience, he is capable of correlating factors of wind, weather, aircraft capabilities, etc., in order to provide optimum control and assistance in aircraft landings.
>
> (LSO NATOPS Manual, 1975)

The LSO's dual responsibilities of safe and expeditious aircraft recovery may sometimes conflict. Borden noted that "to expedite the recovery process, the LSO often must work closer to the extremes of acceptable performance than he would if safety were his sole consideration" (Borden, 1969, p. 16). LSO voice calls promote both safety and an expeditious recovery. They minimize deviations in the approach and expedite the recovery by lowering the bolter rate and minimizing the need for wave-offs. However, unsafe approaches occur despite the combined efforts of the pilot and the LSO. In the critical final seconds of the approach, the LSO changes his role from promoter of a good approach to impartial judge of approach acceptability. At this decision wave-off point, safety becomes paramount to expediting the recovery. Habitual delay by the LSO in switching roles from promoter to judge can serve to increase both the boarding rate and the accident rate.

To fulfill his dual responsibility, the LSO must be able to quickly and accurately perceive the position and trends of the aircraft, predict its immediate future state, and, if required, select the appropriate corrective assistance. An LSO has attained a high degree of perceptual learning through training and experience that enables him to detect and recognize small changes in aircraft dynamics. He must be able to anticipate the effects of these changes and predict the aircraft's future state as well as the probable pilot corrective actions. LSOs describe this complex process as "staying ahead of the aircraft." When the LSO judges that the aircraft has deviated, or will soon deviate, from an acceptable approach, he must immediately select a call to assist the pilot in making the proper correction before the deviation escalates to an unsafe situation.

STUDY TASKS

The study tasks to be performed by HPR were (1) analyze the decision-making process of the LSO during carrier aircraft recovery operations; (2) identify aircraft approach parameters that are related to the LSO's judgement of approach performance; (3) identify situational and environmental variables that influence the LSO's task; (4) estimate the LSO's decision criteria for issuing corrective assistance calls to the pilot; (5) catalogue and analyze the standard and non-standard verbal responses used by LSOs; (6) suggest candidate performance measures applicable to an automated LSO trainer; and (7) synthesize this information in an LSO model suitable for translation to software for application in an automated LSO training device.

SECTION II

STUDY PHASE I

METHODS

Analytic methods were used in the first phase of the study to accomplish study objectives. The methods included observations, interviews, conferences, and reviews of literature and documentation. A summary of the application of these methods is given below.

OBSERVATIONS. Observations of carrier landing operations were performed both at-sea and ashore. Observations ashore were made during Field Carrier Landing Practice (FCLP) at NAS Point Mugu, California, over a three-day period. Two hundred and fifty FCLP approaches of A-7 aircraft were observed during both day and night operations. Observations were made from the LSO's position adjacent to the runway. In addition to observing approaches, HPR personnel gained familiarity with the LSO grading system and descriptive shorthand.

At-sea observations were conducted on the USS ENTERPRISE (CV-65) and USS CORAL SEA (CV-43). On the USS ENTERPRISE, approximately 400 arrested landings were observed during three days and nights of carrier qualification (CQ) training operations. On the USS CORAL SEA, approximately 300 approaches were observed during two days and nights of airwing training operations. The types of aircraft observed included the A-7, A-6, S-3, F-4, F-8, and F-14. Severe weather was encountered on the USS CORAL SEA which enabled observation of LSOs performing their job under very difficult conditions of pitching and rolling deck, rain storms, reduced visibility, and no horizon. On both carriers, the observer was able to monitor radio communication between the pilot, LSO, and other carrier air traffic control personnel.

INTERVIEWS. Interviews were conducted with approximately 20 LSOs during the first phase of the study. Some LSOs were interviewed more than once. At the outset of the study, informal interviews were conducted on the USS ENTERPRISE, USS CORAL SEA, and at NAS Point Mugu. Information gained in the informal interviews was used to structure formal interview forms that were used in subsequent LSO interviews at NAS Lemoore, California, with VA-122 LSOs, and at NAS Point Mugu, with VA-305 LSOs. The formal interviews, approximately two hours long, were conducted individually and in group sessions. Approximately 20 days were required to accomplish the interviews.

Additional interviews were conducted at the conclusion of the first phase of the study to evaluate the results of the study. Five LSOs from VA-122 and VA-192 participated in the evaluation.

REVIEW OF LITERATURE AND DOCUMENTATION. A review of relevant scientific literature, technical reports, Navy manuals and documents provided background material on LSOs, carrier landings, LSO models, simulation, simulator technology and evaluations, perceptual processes, and system analysis modeling. A listing of the important literature and documentation reviewed is contained in the bibliography.

In addition, a summary of carrier landing accidents and incidents was obtained from the Naval Safety Center and reviewed. This summary described 143 major carrier landing accidents from July 1970 through December 1977. The summary was reviewed for LSO involvement as either a causal or contributing factor.

RESULTS

Results of the first phase of the study are incorporated in the structure of the LSO model.

The model is oriented to the A-7 aircraft, but relatively few changes would be required to represent other carrier-based aircraft. The LSO task has a large degree of commonality across aircraft types, but the commonality is by no means complete. Waving a particular aircraft requires the general or common LSO skills and knowledge plus a specific subset of skills related to that aircraft. The differences in the LSO's task between aircraft types have never been systematically described.

The LSO model represents the decision-making of the LSO in terms of call selection and wave-offs. The perceptual and cognitive processes underlying these decisions are far beyond the scope of the model. The model consists of a set of decision rules relating aircraft dynamics to LSO calls. The process by which an LSO selects a call is far more complex than the steps in the model that leads to a call. The process by which an LSO arrives at the decision to give a call is not represented by the model. However, if the model is successful, the call that it selects for a given situation will be the most common standard call that a qualified LSO would give in the same situation.

THE LSO MODEL I: FLOWCHART FORMAT. The symbols and definitions used in the model are given in Table 1. Four ranges are defined, using common LSO terminology and symbols: start (X), in-the-middle (IM), in-close (IC), and at-the-ramp (AR). Aircraft dynamics and flight parameters have been simplified from continuous variables to a categorical (ordinal) scale. For example, angle of attack is either high, normal, or low. Initial estimates of the definition of these categories are given in Table 1. However, these estimates should be interpreted with caution. They are based upon LSO interview data which are subject to the errors and distortions inherent in estimates of physical magnitudes that are reconstructed from memory.

The LSO flowchart model is shown in Figure 1. It is presented in 14 parts which divide the model into separate procedures or subroutines that may be examined individually. The ten procedures are listed with the symbols and definitions in Table 1. Explanatory remarks are presented below for each procedure. They are designed to aid the reader in reviewing the flowchart. They are <u>not</u> intended to be a complete verbal translation of the model. The explanatory remarks serve as a guide, and should be read <u>in conjunction with the flowchart</u>.

TABLE 1. LSO MODEL SYMBOLS AND DEFINITIONS

The following symbols and definitions pertain to both the flowchart format and the call-listing format unless otherwise noted.

RANGE KEY

Symbol	Term	Distance to No. 3 wire	Time to Touchdown*(1)	Notes
X	Start	4600 - 4000 ft	25 - 22 sec	3/4 nm = 4600 ft
IM	In-the-Middle	4000 - 2200 ft	22 - 12 sec	1/2 nm = 3000 ft
IC	In-Close	2200 - 600 ft	12 - 4 sec	1/4 nm = 1500 ft
AR	At-the-Ramp	600 - 0 ft	4 - 0 sec	

*(1) Applies to A-7 aircraft with approximately 28 Kts of wind over deck.

ESTIMATED APPROACH PARAMETER CATEGORY VALUES

GLIDESLOPE

Balls*(2)	Degrees Off
2.0 high	+ 0.64
1.5 high	+ 0.48
1.0 high	+ 0.32
0.5 high	+ 0.16
0.5 low	- 0.16
1.0 low	- 0.32
2.0 low	- 0.64

*(2) 1 ball = 0.32 degrees (19-20 minutes of arc).

SINK RATE

	Rate of Descent *(3)
Very High	> 1200 ft/min
High	1200 - 800 ft/min
Normal	800 - 500 ft/min
Low	< 500 ft/min

*(3) Assumes 30 Kts of wind over deck.

ANGLE OF ATTACK

	Angle of Attack*(4)
Slow	> 18.5 units
Normal	18.5 - 16.5 units
Fast	< 16.5 units

*(4) Applies to A-7 aircraft.

LINE-UP

	Degrees off Centerline*(5)
Left	> 1.5 deg left
Normal	± 1.5 deg
Right	< 1.5 deg right

*(5) No. 3 wire origin at angle deck centerline.

DRIFT

	Drift*(6)
Left	> 20 min/sec left*(7)
None	20 min/sec left to 20 min/sec right
Right	< 20 min/sec right

*(6) These estimates should be considered as gross approximations.
*(7) Relative to angle deck centerline from No. 3 wire origin.

POWER

	Power*(8)
Underpowered	< 2600 lbs/hr
Overpowered	> 3200 lbs/hr

*(8) Applies to A-7E aircraft.

ATTITUDE

	Pitch Attitude*(9)
High	> + 4 deg
Normal	± 4 deg
Low	< - 4 deg

*(9) Relative to normal approach attitude, A-7 aircraft

	Angle of Bank
Left	< 4 deg left
None	± 4 deg
Right	> 4 deg right

LOGIC SYMBOLS

Symbol	Definition
>	Greater than
<	Less than
≥	Greater than or equal to
≤	Less than or equal to

FLOWCHART MODEL SUBROUTINES (PROCEDURES)

Start Loop
Low Procedure
High Procedure
Line-up (LU) Procedure
Multiple Deviation (Mult. Dev.) Procedure
Sink Procedure
Climb Procedure
Drift Procedure
Speed Procedure
Begin Procedure
End Procedure

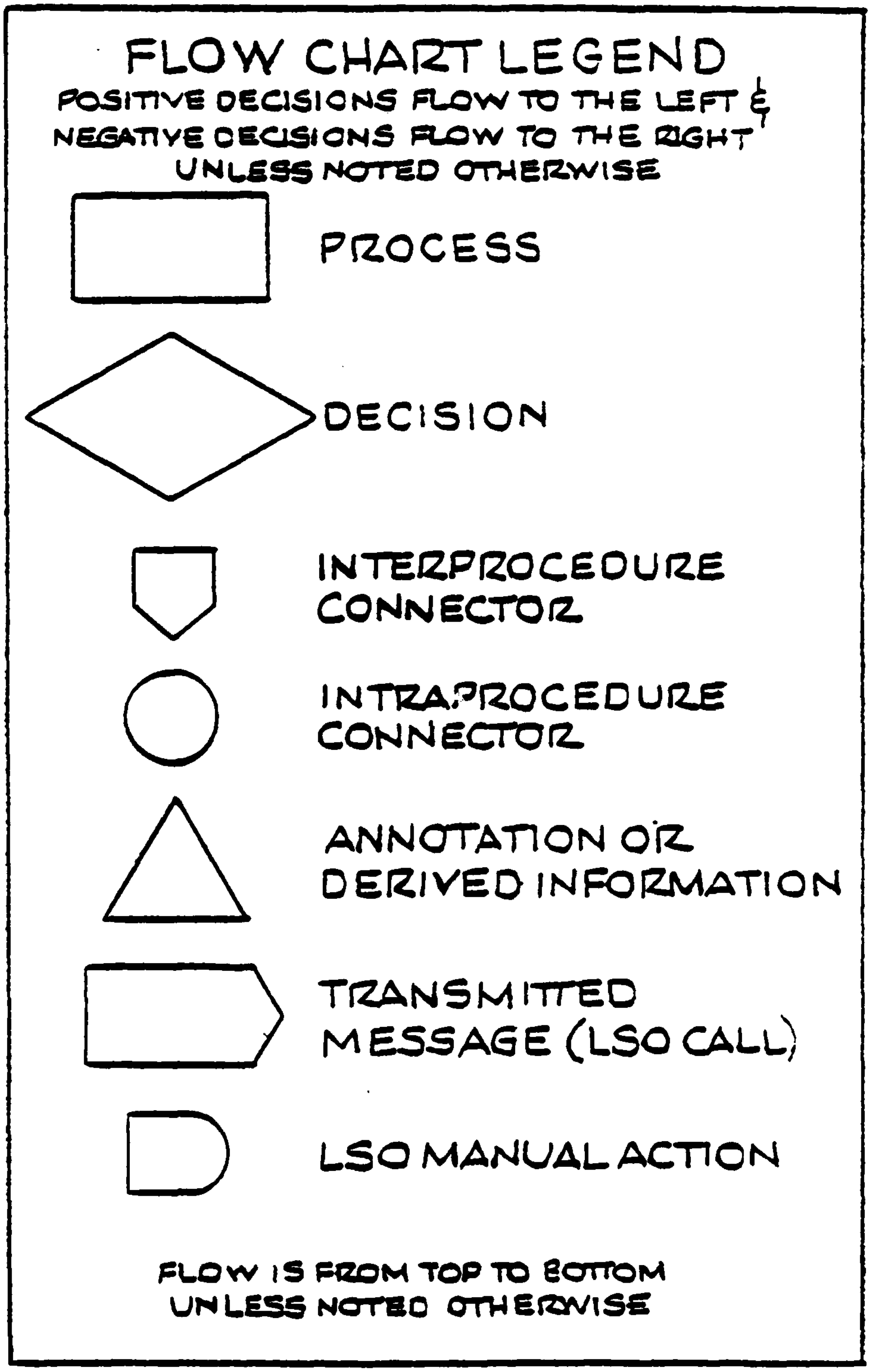

Figure 1. The LSO Model: Flowchart Format Legend (Part 1 of 14)

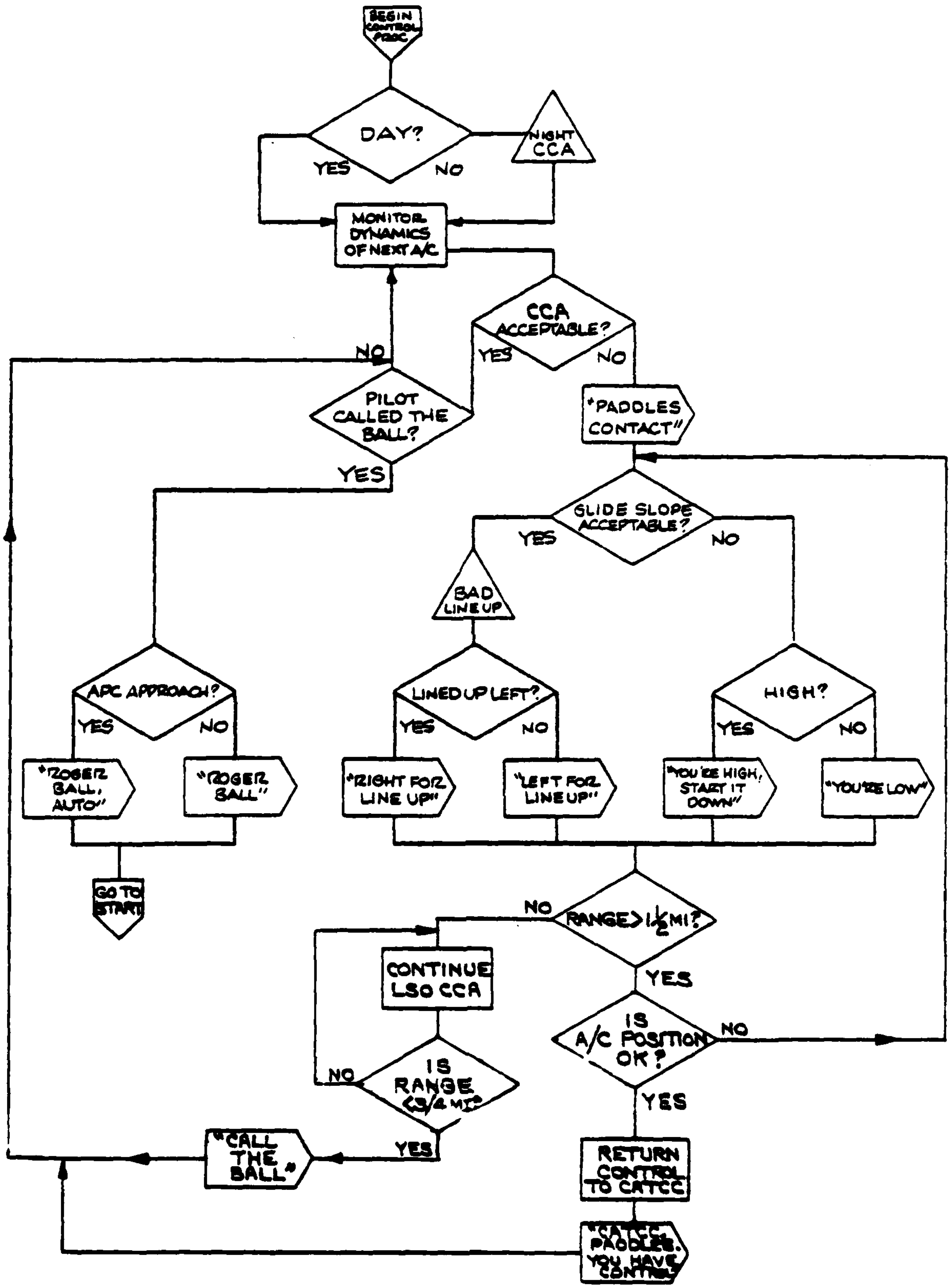

Figure 1. Begin Control Procedure (Part 2 of 14)

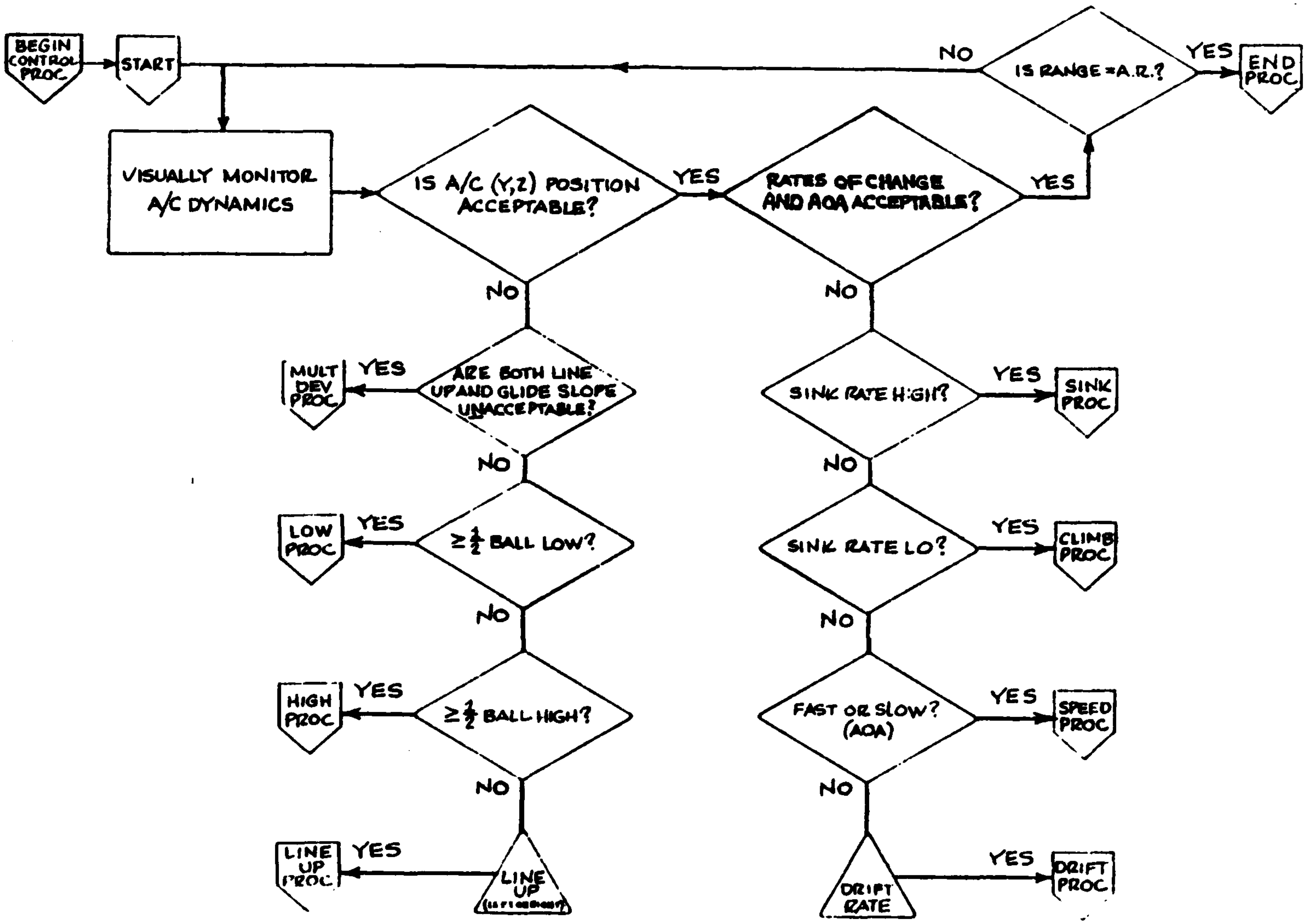

Figure 1. Start Loop (Part 3 of 14)

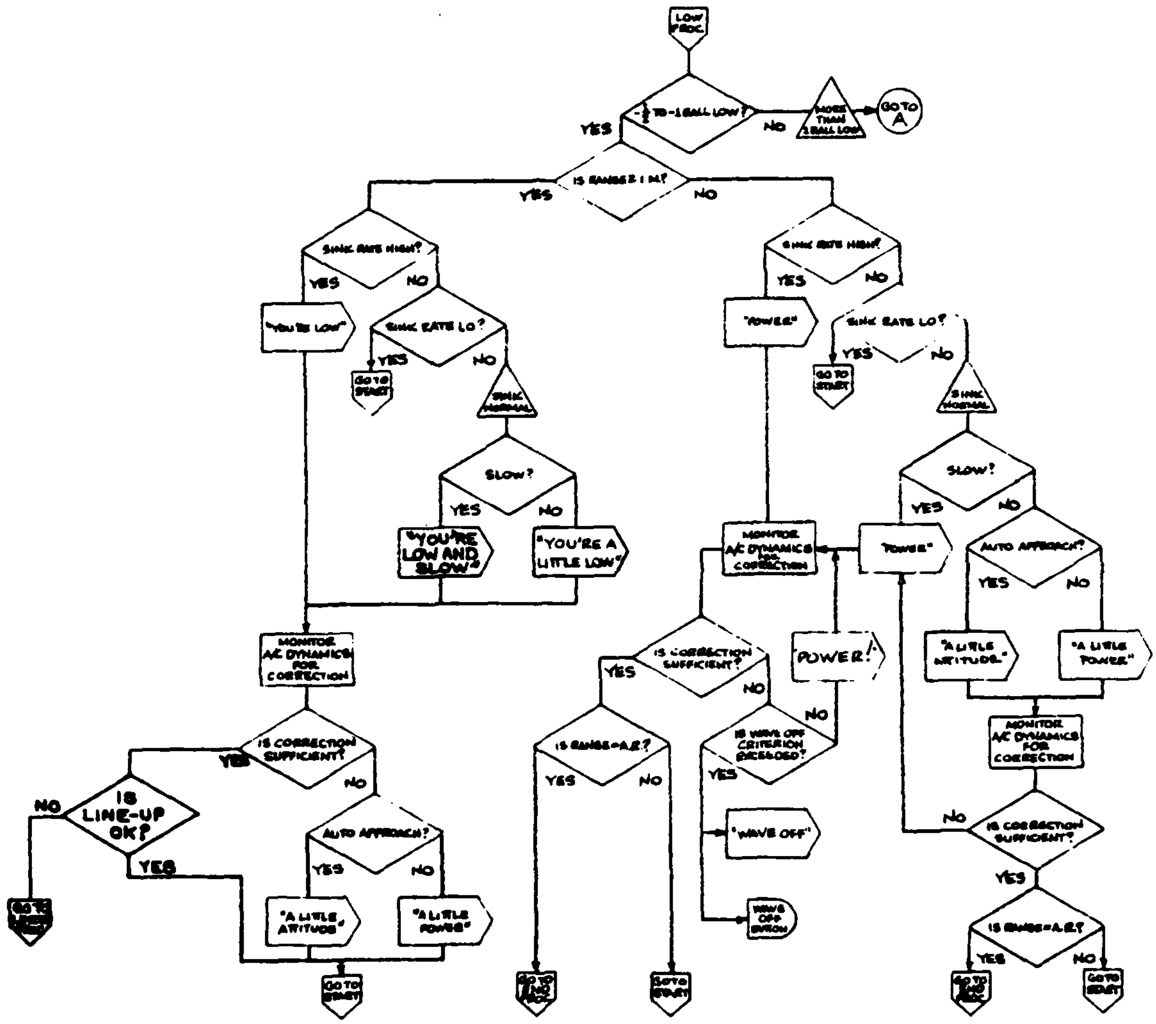

Figure 1. Low Procedure (Part 4 of 14)

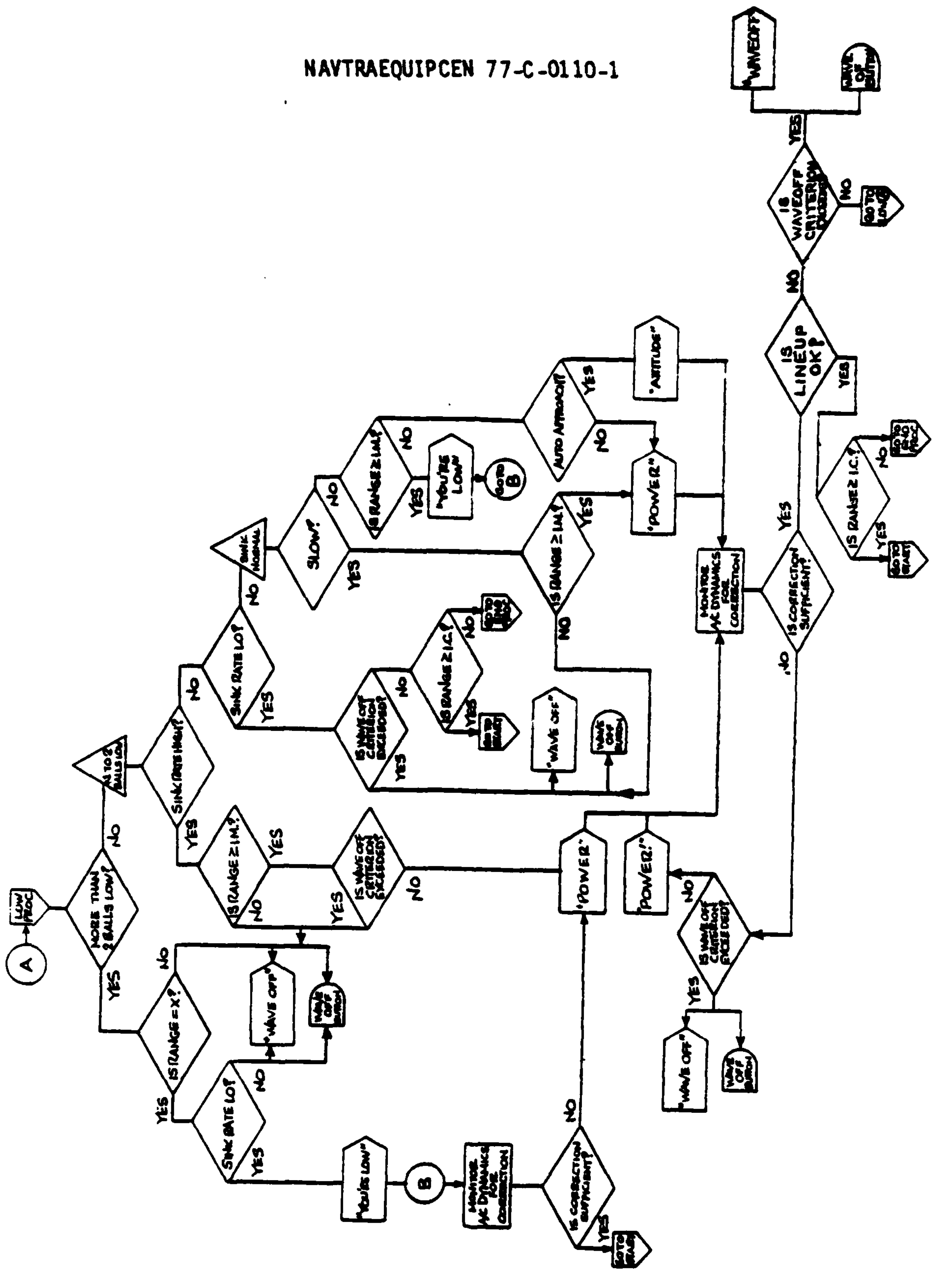

Figure 1. Low A Procedure (Part 5 of 14)

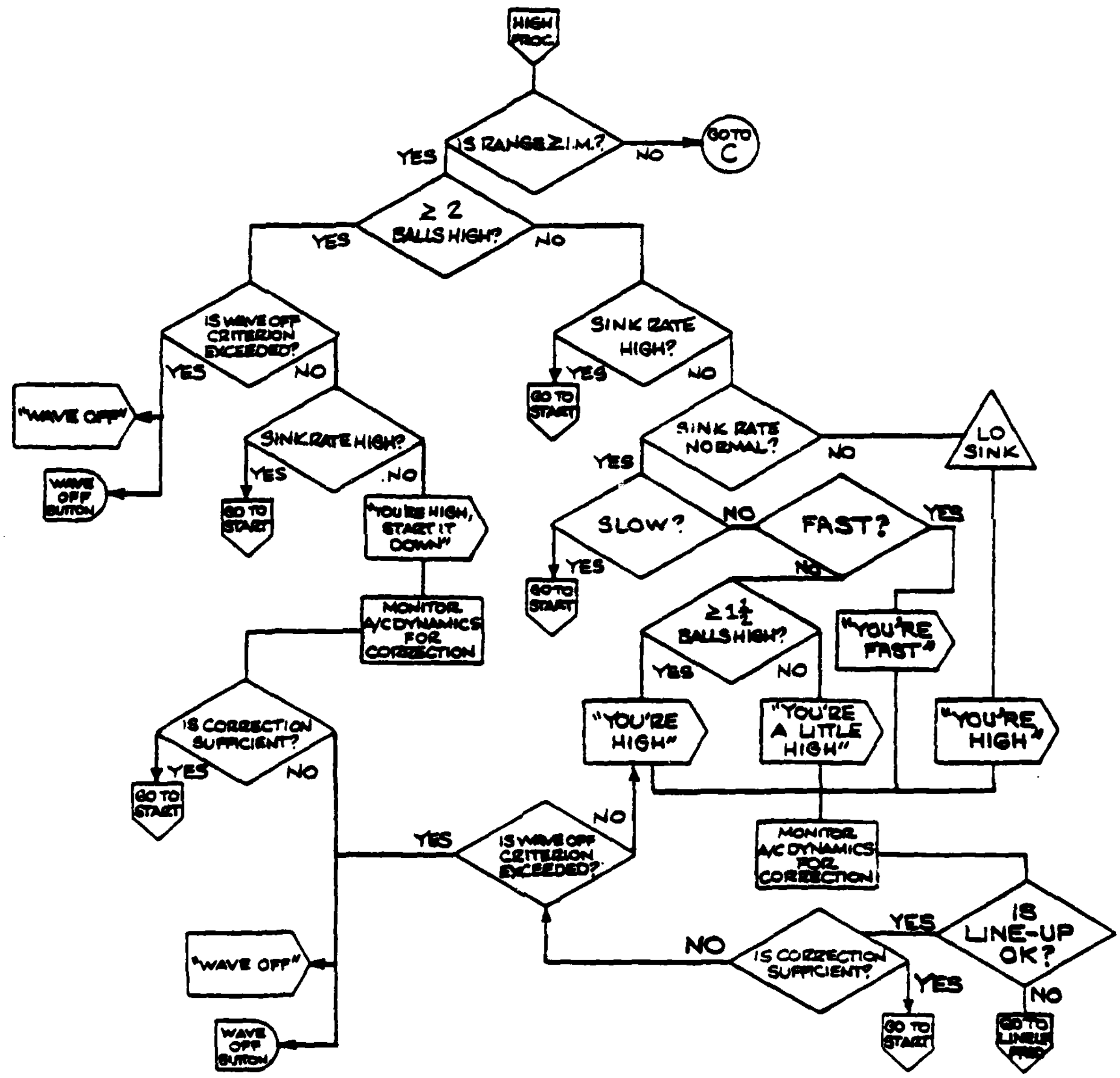

Figure 1. High Procedure (Part 6 of 14)

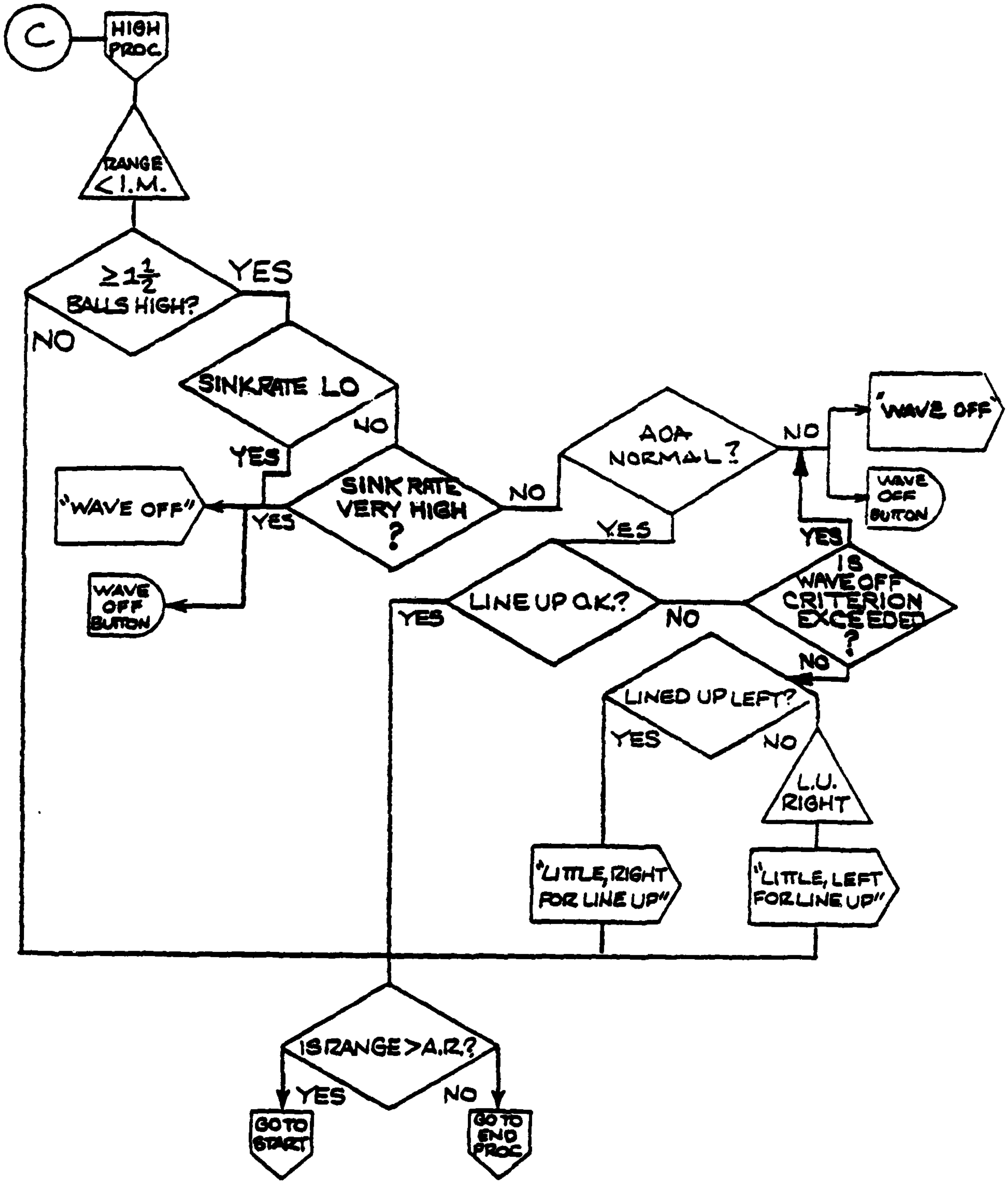

Figure 1. High C Procedure (Part 7 of 14)

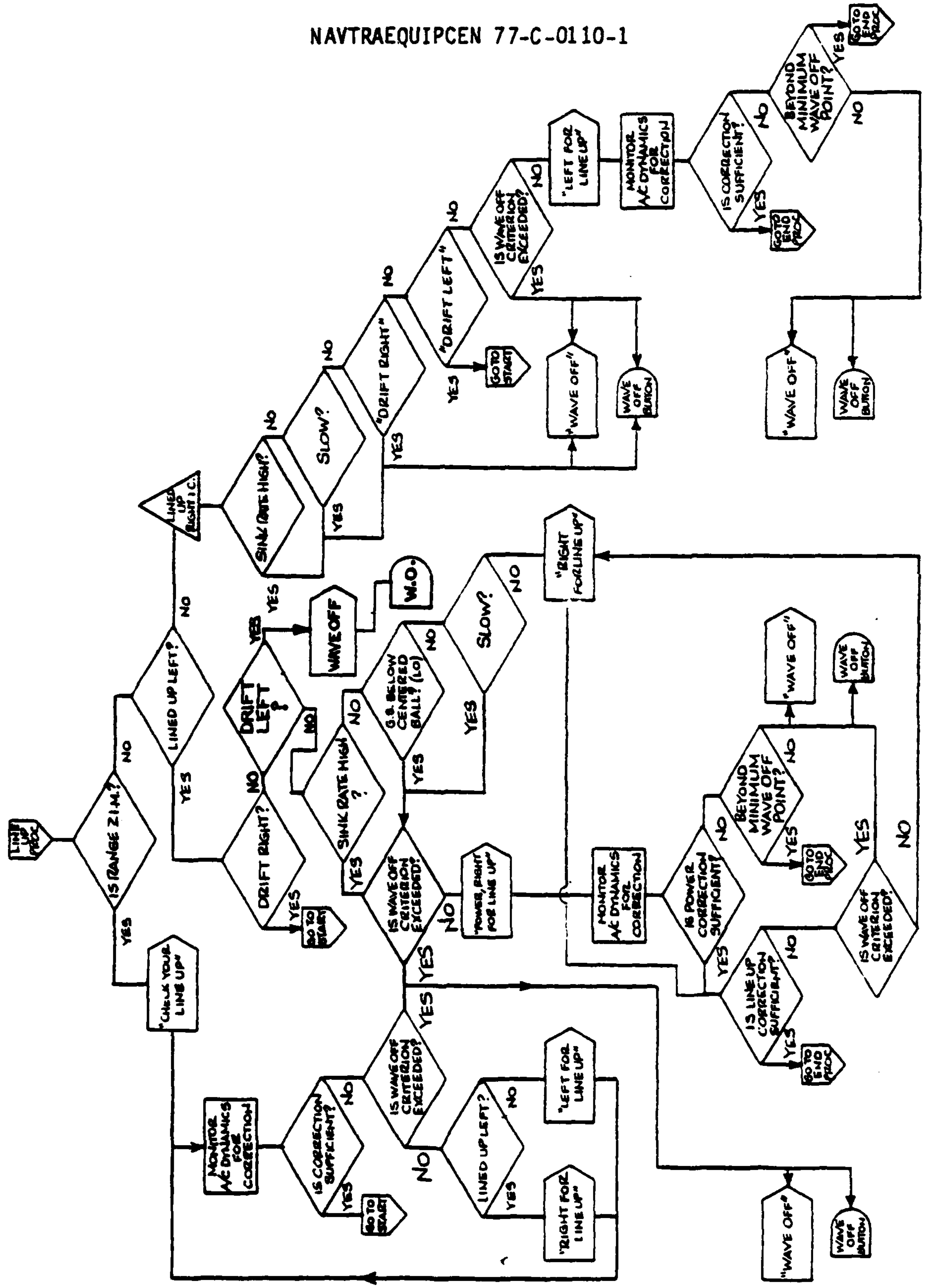

Figure 1. Line-up Procedure (Part 8 of 14)

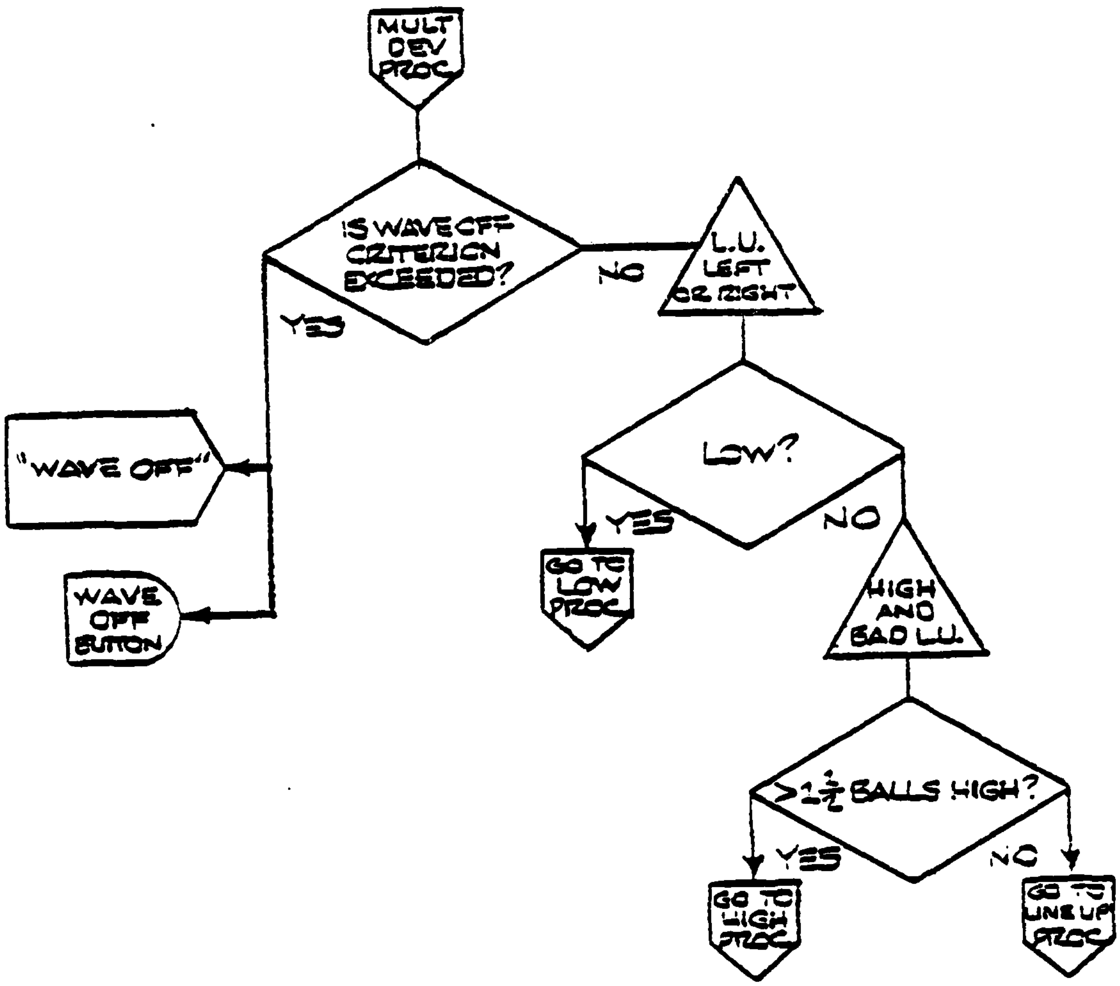

Figure 1. Multiple Deviation Procedure (Part 9 of 14)

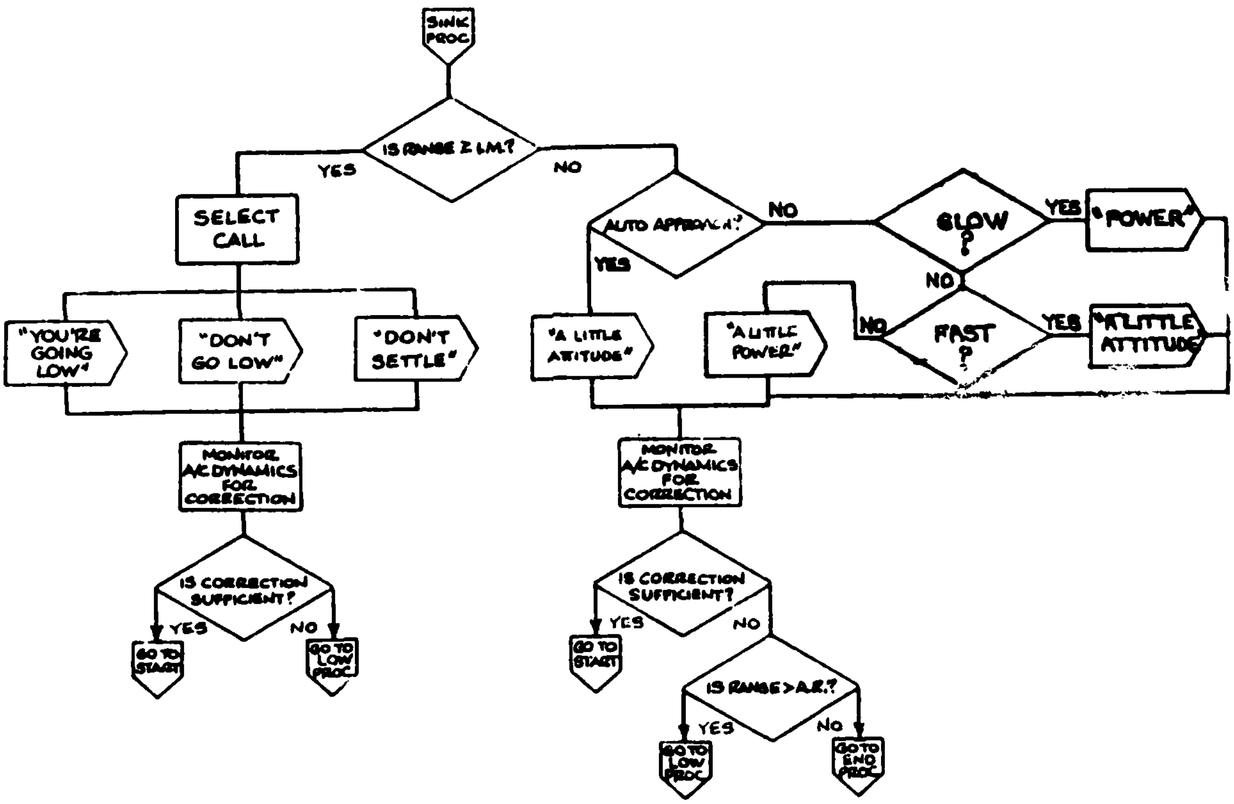

Figure 1. Sink Procedure (Part 10 of 14)

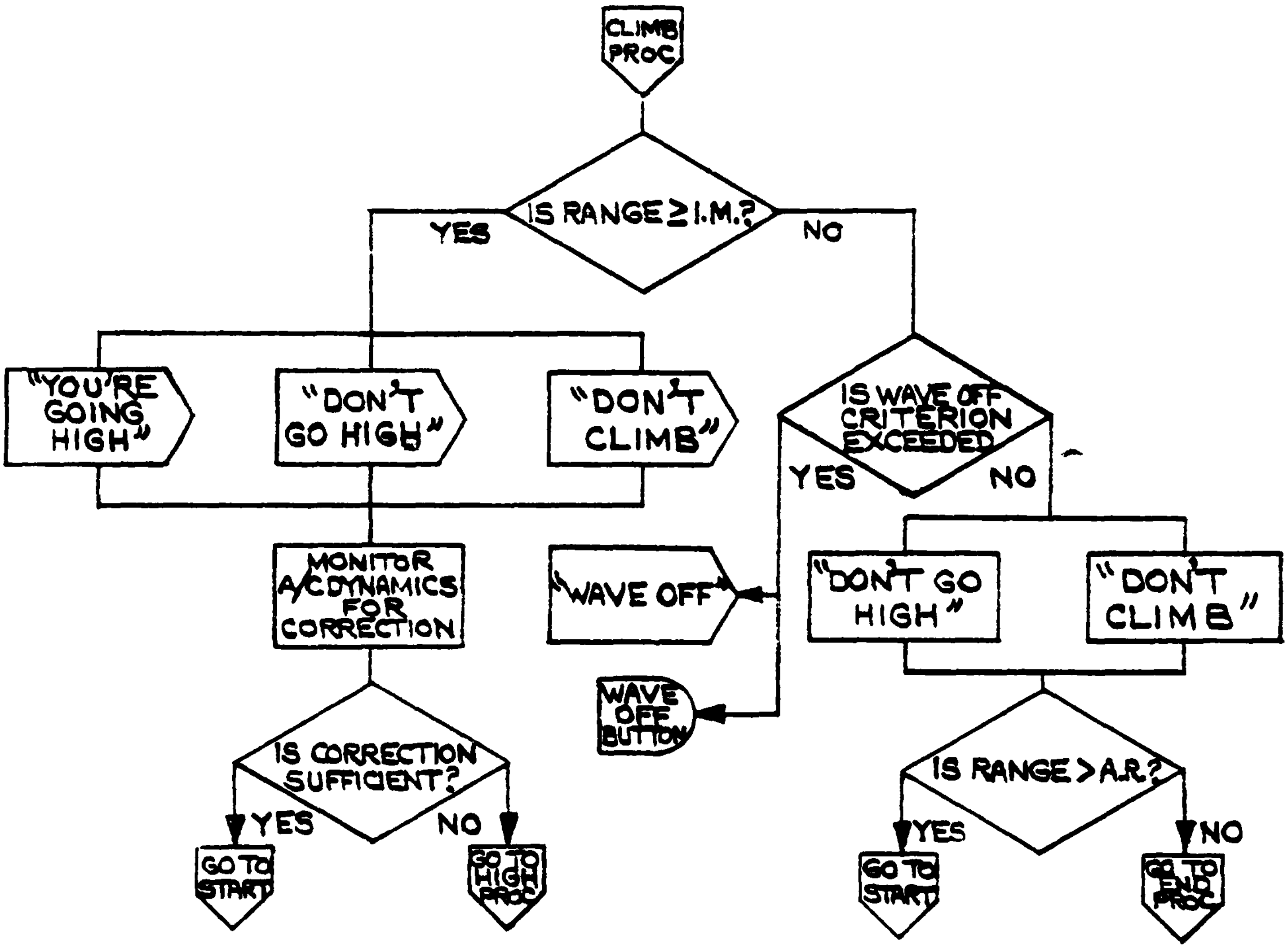

Figure 1. Climb Procedure (Part 11 of 14)

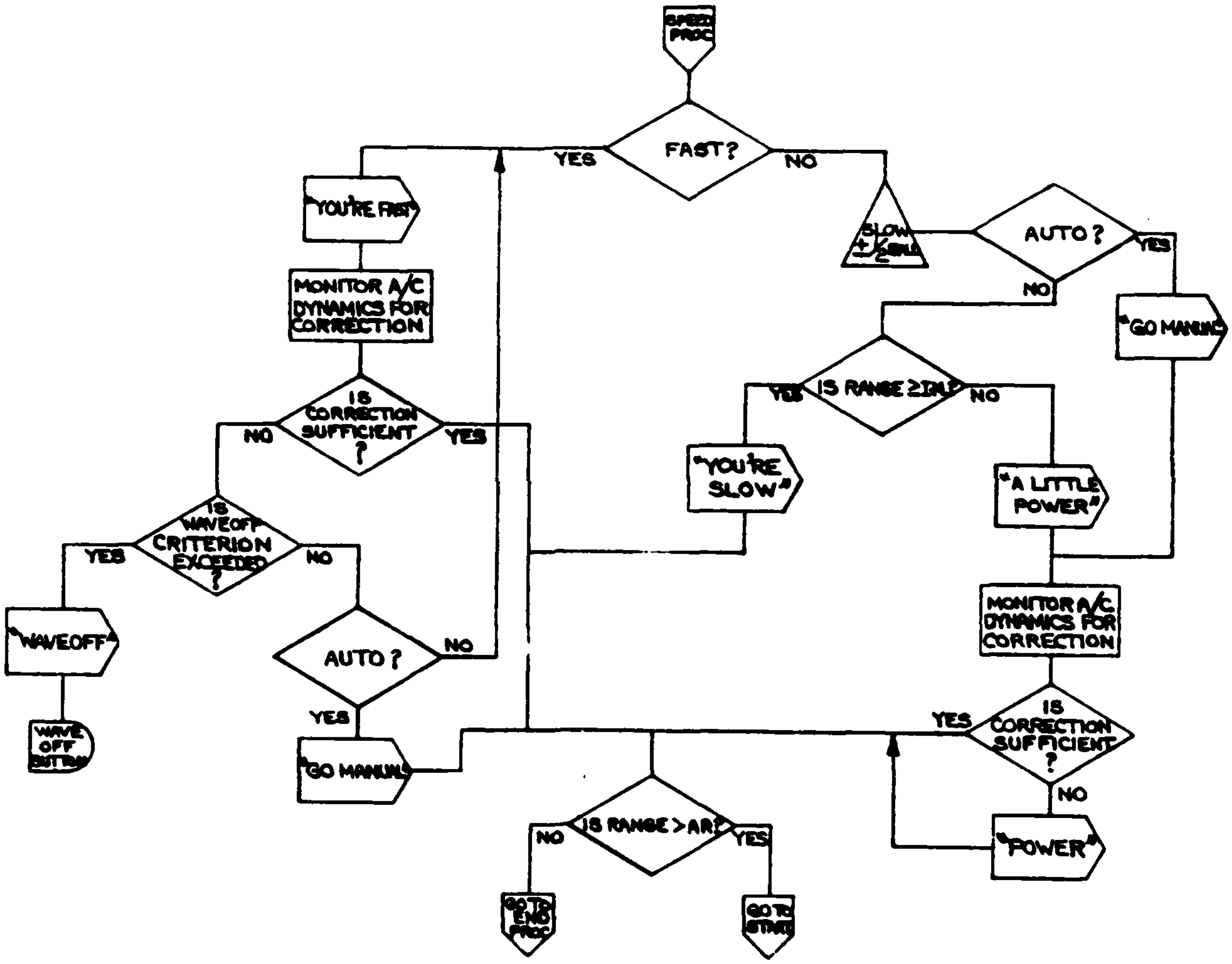

Figure 1. Speed Procedure (Part 12 of 14)

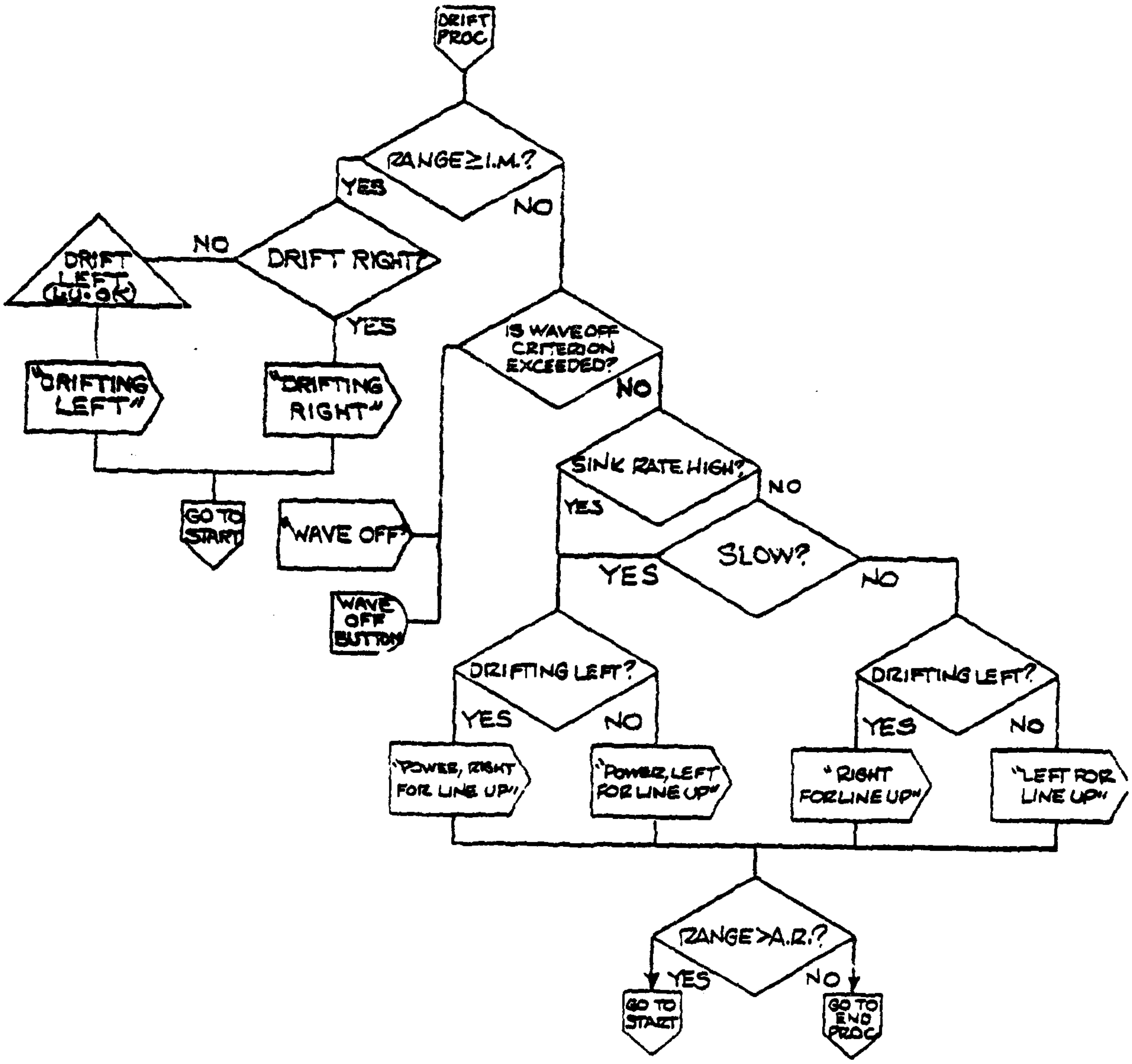

Figure 1. Drift Procedure (Part 13 of 14)

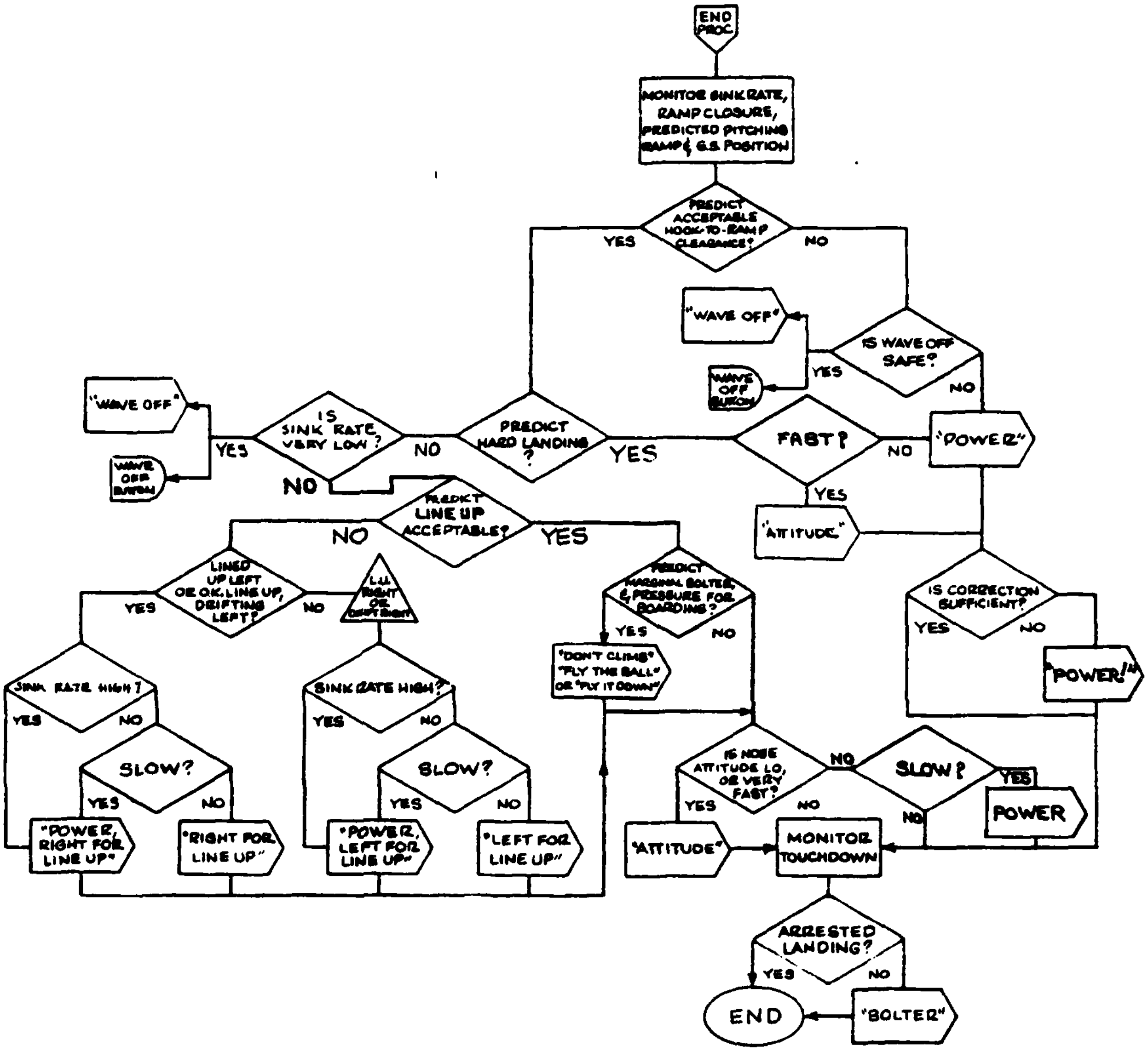

Figure 1. End Procedure (Part 14 of 14)

Begin Control Procedure. This procedure is a prelude to the "Start" loop. Its primary purpose is to represent the relatively uncommon call "Paddles contact." The routine LSO calls "Roger ball" or "Roger ball, Auto" are also represented. They are given at the beginning of each approach in response to the pilot "calling the ball." These calls acknowledge LSO control of the approach and serve as a radio communication check between the LSO and pilot. It is the LSO's prerogative to give the call "Paddles contact" prior to the pilot calling the ball, if he chooses to initiate early control of the approach. This usually occurs when the LSO judges that the initial phase of a straight-in approach at night, under control of Carrier Controlled Approach (CCA), is unsatisfactory. The "Paddles contact" call in the Begin Control Procedure is followed by one of four calls designed to guide the pilot toward a better starting position.

Start Loop. The LSO model enters its fundamental feedback loop at "Start." The loop begins with the monitoring of aircraft dynamics. The first decision function of the model is whether or not the position of the aircraft is acceptable. Position refers to the location of the aircraft relative to the projected centerline of the carrier angle deck (line-up), and the idealized glideslope, given a perfectly stabilized lens system. If the position of the aircraft is acceptable, the model proceeds to the second decision function "are the rates of change of position acceptable." If sink rate (vertical velocity), drift rate (horizontal velocity with respect to line-up), and angle of attack are acceptable, the model loops to "Start" and the process is repeated, beginning with monitoring the aircraft dynamics.

The model makes a distinction between the monitoring process and the related decision functions. This is an artificial distinction intended to simplify the model. In practice, the monitoring process undoubtedly is continuous throughout the approach. That is, LSOs make decisions, formulate corrective assistance, make trasmissions to the pilot, and at the same time monitor approach performance. Although micropsychological issues such as parallel processing are beyond the scope of this study, the authors assume that LSOs operate in a parallel mode. However, to simplify the model, the monitoring process has been depicted as a serial process and separated from other LSO functions throughout the model.

The "Start" loop in the model continues as long as aircraft approach dynamics remain acceptable. This loop represents the completely acceptable approach when no control action is required by the LSO. To conveniently represent the ending of this basic loop, an additional decision function is included that branches to an "End Procedure" when the aircraft reaches the "At-the-Ramp" (AR) position. The End Procedure controls the aircraft during the terminal phase of the approach, from just prior to passing over the ramp until touchdown. The model terminates if an arrested landing occurs, or the call "bolter" is given, if the aircraft fails to engage a pendant. The End Procedure also includes some last-second corrective assistance calls that will be discussed later.

If the aircraft position becomes unacceptable during the approach, the initial decision function in the "Start" loop steps through a series of decision functions to determine the type of deviation--Low, High, Line-up, or a combination of altitude and line-up deviations. When the deviation is identified, the model branches to the appropriate procedure--Low Procedure, High Procedure, Line-up Procedure, or Multiple Deviation Procedure. Similarly, if the rates of change (trends) are unacceptable, the second decision function in the "Start" loop branches to Sink Procedure, Climb Procedure, Drift Procedure, or Speed Procedure.

Low Procedure. The Low Procedure is the most critical from the standpoint of safety of flight. It is also the most lengthy and complex procedure in the model. It is divided arbitrarily into two subdivisions--Low and Very Low. the initial Low Procedure decision function separates these two subdivisions by branching any deviation greater than -1 ball to the "Very Low" category (the Low A Procedure in the model). The critical variables for the decisions within the Low Procedure are Range, Sink Rate, Angle of Attack, and Pilot Correction. If Range is "In-the-Middle" or greater, LSOs will tend to use informative calls ("You're a little low"). If Range is "In-Close," LSOs will tend to use imperative calls ("Little power") for a deviation of equal magnitude.* Sink Rate is used to determine the seriousness of a low deviation. For example, the LSO is unlikely to give a low call at the In-the-Middle position if the aircraft is 1/2 to 2 balls low and the sink rate is low (i.e., the aircraft is climbing with respect to the glideslope). The LSO will infer that the pilot is making a proper correction to the low deviation. However, if sink rate is high, the LSO will immediately give a corrective assistance call such as "You're low," or perhaps even "Power" if the sink rate is excessively high.

Another critical variable for the Low Procedure is pilot correction. Selection of a call is based partly on the pilot's response to the previous call. This creates a more complex LSO model, but the LSOs interviewed consistently described the importance of formulating a particular call based on the pilot's response to the previous call. For example, if the call "You're low" receives an insufficient response from the pilot, the LSO is likely to call for a "Little power," even though the low deviation itself is not great enough to elicit a power call. Furthermore, if a pilot does not respond to a "Power" call (pilot response is mandatory to a Power call), the LSO is likely to command a "Wave-off" even though the deviations alone may not be great enough to warrant a wave-off. In general, the model branches to a more "serious" call if a pilot correction is insufficient; if the correction is sufficient, it branches to the start (visually monitor aircraft dynamics), or to the End Procedure, if the range is equal to At-the-Ramp.

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* Note that deviations of equal magnitude, such as 1 ball low, equate to different absolute deviations at different ranges. At 1/2 mile (In-the-Middle) 1 ball low equals about 16 feet. At 1/4 mile (In-Close) 1 ball low equals about 8 feet.

Another critical variable of the Low Procedure is angle of attack. If a low aircraft is also slow, the model will give a stronger call than if the aircraft is "on-speed." Stronger calls may mean an imperative rather than an informative call, or, in the case of power calls, three levels of strength are distinguished in the model--"A little power"; "Power"; and "Power!" Alternative calls for power are used for aircraft making auto-throttle approaches ("Auto")--"A little attitude" is used instead of "A little power" and "Attitude" is used instead of "Power." A "Power!" call is used for both Auto and manual approaches, and requires the pilot to break out of Auto by manually adding power.

The Very Low Procedure, Low A, is functionally similar to the Low Procedure. However, stronger LSO calls are used because of the larger deviations (more than 1 ball low). An arbitrary "worst case" decision criterion is included in the model for aircraft that are low at the start of the approach. In this case, a "Wave-off" is given when the aircraft is more than 2 balls low ("off the bottom" of the Optical Landing Aid) unless the sink rate is low (climbing with respect to the glideslope). At closer ranges, a wave-off would be given for a less serious deviation, but the model decision function is simply stated, "Is wave-off criterion exceeded?" Wave-off criteria will vary according to situational variables. Therefore, explicit wave-off criteria usually are not incorporated in the model in order to accommodate the effects of situational variables. Gross estimates of the wave-off criteria under normal conditions were obtained by LSO interviews, and are reported in the call-listing format of the model, given later in this report.

A "Wave-off" call terminates an approach and the model ends. This feature of the model is consistent with Navy doctrine which states that the pilot is required to respond immediately, without exception, to a wave-off by adding full military power and rotating the nose to the best climb attitude.

The Very Low Procedure incorporates the same variables as the Low Procedure--range, sink rate, angle of attack, and pilot corrections. The LSO calls included in this section of the model are "You're low," "Power," (or "Attitude" if Auto), "Power!," and "Wave-off." The procedure was modeled on the premise that the LSO's ultimate objective with a low approach is to ensure a safe clearance over the ramp (hook-to-ramp clearance). Power calls accomplish this objective by requiring the pilot to add sufficient power to fly the aircraft up to the glideslope. If the LSO does not observe an immediate decrease in sink rate in response to the "Power" call, a "hard" power call ("Power!") or a "Wave-off" will be given. The process "Monitor aircraft dynamics for correction" includes listening for an increase in power, particularly as range decreases. At close ranges, power changes are more audible and less delayed. The situational variable "deck noise" is important here, since an aircraft turning up behind the LSO platform or launching from a catapult may mask power changes of the approaching aircraft.

The Very Low Procedure, in summary, describes the LSO's attempt to get the aircraft up on the glideslope by the use of power calls. If the pilot response is insufficient, a "Wave-off" will be given; if sufficient, the sink rate becomes low (climb with respect to glideslope), the model branches to the Start Procedure, or to the End Procedure, depending upon range.

High Procedure. The model enters the High Procedure when the initial decision function of the "Start" loop detects that the aircraft is more than 1/2 ball above glideslope and the line-up is acceptable. The major variables considered in the High Procedure are magnitude of the high deviation, sink rate, and range. LSO interview data indicate that the objective is to correct a high approach gradually, avoiding a very high sink rate which can lead to serious consequences such as a hard landing or a ramp strike. Particularly with the A-7, the LSO will not call the aircraft for a high approach at the in-close range, to prevent a dangerous overcorrection by the pilot. Rather, LSOs will allow the high approach to continue, preferring to have the approach terminate in a bolter rather than risk an excessively high sink rate in-close. The High Procedure of the LSO model is patterned accordingly; hence the importance of the first decision function involving range.

Line-up calls are included in the High Procedure because they can be used to correct high deviations without the risk associated with power reduction corrections. That is, line-up corrections tend to be accompanied by a loss in altitude (settling) that occurs from loss of lift when angle of bank is changed. Although high calls often are not used when the aircraft is In-Close, because of the risk of ramp strike, LSOs may use line-up corrections for a high approach In-Close as a means of simultaneously correcting both bad line-up and high glideslope discrepancies. This strategy may not be appropriate for all aircraft types.

The High Procedure, like the Low Procedure, addresses the combination of position on the glideslope and rate of change of position (sink rate). For example, if an aircraft approach is high between the Start and In-the-Middle range, no LSO call will be given if the sink rate is above normal, i.e., the pilot is correcting. If the angle of attack and the sink rate are normal, the call "You're a little high" will be given, but if the sink rate is low, the call "Don't go high" will be given. After the call, the aircraft dynamics are monitored for correction, and the model branches to the start if the correction is sufficient. If the correction is not sufficient, i.e., an increase in sink rate is not established, the call "You're high" is given. If a sufficient correction still has not been made, the model will give a "Wave-off" when the aircraft exceeds the wave-off criterion. A "Wave-off" will also be given In-Close if the aircraft is more than 1 1/2 balls high with a low sink rate (climbing with respect to the glideslope). At the start range, the High Procedure will give the call "You're high, start it down" when the aircraft is more than 2 balls high, unless the sink rate is low, in which case, a "Wave-off" is given.

A High glideslope position between the ranges of In-Close and At-the-Ramp can be particularly dangerous if the aircraft is not on-speed. A High/Fast will probably require wave-off because only a drastic correction could salvage the approach. Similarly, a High/Slow may receive a "Wave-off" because it could deteriorate into a dangerously excessive sink rate.

Non-standard calls (not listed in the LSO NATOPS Manual) are frequently given by LSOs to correct deviations in the approach. These calls are listed in the Call-Listing Format of the model (see Table 2). The non-standard calls for a high approach emphasize the LSO objective of correcting the deviation gradually, such as "Ease it down," "Start it down," "You're working high," and "Center the ball." These calls are intended to prevent an excessive power reduction which can lead to a high rate of descent In-Close. These calls are probably used more frequently with the A-7 aircraft, because an excessive power reduction for a "High In-Close" is particularly dangerous in the A-7.

Multiple Deviations Procedure. The model branches from the "Start" loop to the Multiple Deviations Procedure when deviations exist in both glideslope and line-up position. When deviations exist in both parameters, a "Wave-off" may be given even though the magnitude of the deviation in any one parameter is not great enough to warrant a wave-off. The decision function "Low" is the key to the Multiple Deviations Procedure. If low, the model branches to the Low Procedure, emphasizing that a low approach has precedence over line-up deviations. If Multiple Deviation consists of a high deviation greater than 1 1/2 balls plus a deviation in line-up, the model branches to the High Procedure. The use of line-up calls within the High Procedure was discussed previously. The Multiple Deviations Procedure branches to the Line-up Procedure for a combination of line-up deviation with a high deviation less than 1 1/2 balls.

Line-up Procedure. The model enters the Line-up Procedure whenever a deviation in line-up position is detected in the "Start" loop and the glideslope data indicate that unacceptable line-up is any deviation greater than approximately 1 1/2 degrees from the projected centerline of the angle deck, with the landing zone as the origin. For ranges between the Start and In-the-Middle, the procedure gives the call "Check your line-up." An alternative standard NATOPS call for this situation is "You're lined up left/right," but the LSOs interviewed never use this call. They felt that the call "You're lined-up-right" could be confused with the commonly used call "Right for line-up." Therefore, "Check your line-up" is the only line-up call in the model for ranges beyond In-Close. Other LSOs disagree with this strategy, and advocate telling the pilot where he is ("You're lined-up left/right") even at the longer ranges.

After the call "Check your line-up," the model monitors angle of bank and drift rate to determine that a correction has been initiated. If not initiated, the Line-up Procedure may command a wave-off or give the call "Right (left) for line-up."

The primary objective of the Line-up Procedure is to assist the pilot in achieving touchdown within approximately 10 feet of centerline.* A secondary objective is to accomplish this without a loss of altitude which can accompany line-up corrections. As previously mentioned, this can have serious consequences when the aircraft is In-Close. Therefore, precautionary decision functions are included in the Line-up Procedure to prevent an undesirable "settle" by using the call "Power, right/left for line-up." These decision functions establish that the aircraft is on, or slightly above, glideslope, does not have a high sink rate, and does not have a "slow" angle of attack. If these conditions are met, the call "Right for line-up" is given. If any of these three conditions is not met, the model will either terminate the approach, if the wave-off criterion is exceeded, or give the call "Power, right for line-up."

Another variable that influences the Line-up Procedure is aircraft drift. Drift has a similar importance to the Line-up Procedure as sink rate has to the Low and High Procedure. The model, before making a line-up call, will determine if the aircraft is drifting left or right. If the aircraft is In-Close and lined up to the left, for example, but is drifting left to right, the procedure will branch to the start loop and not make a call. The model assumes that the pilot has introduced the proper line-up correction.

Aircraft are more likely to develop line-up deviations to the left of centerline than to the right. This is undoubtedly the result of the 10° angle between the centerline of the landing area and the longitudinal axis of the ship. The approach to the angle deck causes the carrier to move to the right of the aircraft throughout the entire approach. As a result, aircraft tend to develop line-up deviations to the left. The call that is most frequently used to correct this tendency is "Right for line-up," especially when the aircraft is In-Close. At short range, this call is preferred over "Check your line-up" because it does not require the pilot to evaluate the direction of the deviation and decide upon the appropriate response. "Right for line-up" speeds line-up correction, and enables the pilot to concentrate on glideslope control at the In-Close range.

Some controversy exists among LSOs regarding the call "Left for line-up." A minority of LSOs do not believe the call should be used to correct line-up deviations when the aircraft is In-Close or At-the-Ramp. They feel that this call can cause a right-to-left drift to develop, which, if uncorrected, can cause the aircraft to go over the port side of the angle deck after arrestment. These LSOs prefer to wave-off an aircraft that is lined up

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* A line-up deviation greater than 15 feet at touchdown can damage the arresting gear pendant, the hook of the aircraft, or the aircraft itself. If the aircraft is drifting left or right at touchdown, it can cause the aircraft to depart the landing area.

to the right at the In-Close range. Most of the LSOs expressing this opinion had been LSOs on small deck carriers where the risk of this mishap is greatest. (These carriers now play a less significant role in fleet operations.) The majority of LSOs interviewed did not object to the call "Left for line-up," and therefore it is included in the Line-up Procedure of the LSO model. However, the wave-off criteria are more stringent for line-up deviations to the right of centerline. A "Wave-off" will be given by the Line-up Procedure for right-line-up unless sink rate, angle of attack, and drift rate are within narrow limits.

Sink Procedure. The second decision function in the main monitoring ("Start") loop determines whether the rates of change of the aircraft position are acceptable. Since the first decision function deals with aircraft position, the rate-of-change decision function is reached only if the aircraft position is acceptable. The three subroutines under the decision function, Sink Procedure, Climb Procedure, and Drift Procedure, apply to cases where the aircraft position is acceptable, but the rates of change (trends) are not acceptable. These procedures tend to be simpler than the position deviation procedures, because the aircraft is on (or nearly on) the glidepath, but is developing an unacceptable trend.

The Sink Procedure describes the action taken by LSOs to arrest an excessive sink rate, when an aircraft is passing through the glideslope (±1/2 ball). According to LSO interviews, this situation is frequently encountered when the pilot overcorrects for a high position by an excessive power reduction, or fails to properly countercorrect by adding power as the glideslope is approached. The LSO calls given by the Sink Procedure depend on range. "You're going low," "Don't go low," or "Don't settle," typically are used from the Start to the In-the-Middle range. Calls used at ranges less than In-the-Middle tend to be imperative rather than informative--"A little power," or if the approach is being made with autothrottle, "A little attitude." A common non-standard (NATOPS) call is "Don't go through it," meaning don't go through the glideslope. The Sink Procedure monitors aircraft dynamics for a proper power correction to stop the sink rate. If the correction is sufficient, the model branches to the start, and if insufficient, it branches to the Low or End Procedure.

Climb Procedure. The Climb Procedure is entered in the model when the aircraft is approximately on the glideslope (±1/2 ball), but has an insufficient rate of descent to maintain glideslope position (climbing relative to the glideslope). According to LSO interviews, this situation occurs most frequently when the pilot overcorrects from a low position by adding power and fails to countercorrect by reducing power as the glideslope is approached. In this situation, LSOs must be careful to avoid making a call that leads to a dangerous over-reduction of power at the In-Close range. This can result in an excessive sink rate, which, in turn, can result in a hard landing or ramp strike. Most LSOs interviewed said they would rarely, if ever, give a call such as "Don't climb" or "Don't go high" at the In-Close range. They would rather allow the pilot to make his own correction, or bolter, than risk overcorrection that would lead to an accident. The Climb

Procedure incorporates this LSO strategy by restricting the calls "You're going high," "Don't go high," or "Don't climb," to an aircraft range equal to or greater than In-the-Middle. However, if the range is In-Close, the call "Ease it down" is made and the model branches to the Start or the End Procedure. Some LSOs advocated that no call or "Don't go high" should be given here, rather than "Ease it down."

If pilot response is insufficient to one of the first three calls of the Climb Procedure, the model branches to the High Procedure. If the correction is insufficient, the model branches to Start.

Speed Procedure. The model branches to the Speed Procedure when the glideslope position is acceptable, but the angle of attack is either fast or slow. LSOs cannot describe precisely how they judge angle of attack (AOA) since it is a combination of pitch-attitude and power, but they state that their perception is more accurate than can be obtained by monitoring the approach lights. (Approach lights display changes of ±1 unit of angle of attack, which is equivalent to approximately 1.7 degrees of pitch attude in the A-7.) The model makes the call "You're fast" outside the In-Close position. This call is not given by A-7 LSOs at the In-Close range to avoid an excessive power reduction, but a wave-off may be given In-Close for an excessively fast condition. For a slow deviation, the model makes the call "You're slow" or "Don't decel (decelerate)" In-the-Middle range. In-Close, the model gives the call "A little power" for a slow condition.

Drift Procedure. The Drift Procedure is entered in the model when glideslope and line-up position are acceptable but the rate of change of line-up (drift) is unaccaptable, i.e., the aircraft is drifting through the projected carrier angle deck centerline. This situation is likely to occur in two circumstances: (1) overcorrection of a line-up deviation by the pilot, and (2) the normal drift resulting from the relative motion of the carrier away from the aircraft. If a drift rate problem occurs at In-the-Middle range or beyond, the Drift Procedure gives the call "Check your line-up," and returns to the Start. However, if the pilot fails to respond to this call, the aircraft will very quickly be outside of the acceptable limits of line-up, and the model will branch to the Line-up Procedure.

If the range is less than In-the-Middle, the Drift Procedure determines the direction of drift. For a left drift, the call "Right for line-up" is used unless the sink rate is high or angle of attack is slow. In either of those cases the call given is "Power, right for line-up." The equivalent calls are given for a right drift, that is, "Left for line-up," or "Power, left for line-up." A "Wave-off" also may be commanded for drift in either direction.

End Procedure. The End Procedure begins approximately two or three seconds prior to the aircraft crossing the ramp and ends with aircraft touchdown. Some LSOs use the term "Over the wires" to refer to the last one or two seconds of the approach. The fundamental objective of the LSO in this terminal phase of the approach is to ensure that there is sufficient clearance between the aircraft and the ramp of the carrier (hook-to-ramp clearance). The other important objectives are to achieve acceptable sink rate, line-up/drift and speed.

The aircraft dynamics are judged with relation to deck motion to predict hook-to-ramp clearance. Power calls are given if, for example, the pitching deck is coming up and predicted to reach a point that will not provide sufficient hook-to-ramp clearance based upon the predicted position of the aircraft at the ramp. Power calls are also given to prevent a hard landing if the pilot reduces power In-Close. A power call will reduce an excessive sink rate that may have resulted from the power reduction. Line-up calls will be given, such as "Right for line-up," or "Power, right for line-up" to prevent excessive off-center touchdown or excessive drift. The controversial calls "Don't climb," "Fly the ball," or "Fly it down," are included in the End Procedure. Although potentially dangerous, these calls are used by many LSOs in situations where a slightly high overpowered approach may lead to a bolter. These calls are more likely to be used if the LSO knows the pilot, or if the operational pressure for boarding rate is high, and any bolter becomes an added burden to the recovery. Some LSOs object to these calls because they can induce an excessive sink rate, and potentially, an accident. Some guidelines within the LSO community would seem to be appropriate regarding the use of these calls.

Another call found in the End Procedure, "Attitude," is used to prevent touchdown on the nose wheel or when the AOA is very fast. This call requires the pilot to rotate the nose to the proper landing attitude. The final steps of the End Procedure represent the LSO observing the touchdown. If an arrestment is not made, the call "Bolter" is given. The model terminates upon arrested landing.

THE LSO MODEL II: CALL-LISTING FORMAT

The Call-Listing format of the LSO model is presented in Table 2. It contains approximately the same information as the Flowchart format. Standard LSO NATOPS calls are listed with the estimated aircraft dynamics that would elicit the call under normal circumstances. (The quantitative estimates of the categorical variables were given earlier with the Flowchart model, in Table 1.) Important situational variables that apply to a call are given, as well as the expected pilot response and related LSO strategies or techniques. Common non-standard LSO calls are presented as alternatives that may be used in the same situation. The table is presented in a two-page format, with calls, relevant variables and associated values on the first of a pair of pages and comments on pilot and LSO behavior on the second.

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TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 1 of 10)

	Informative LSO Calls	Glide-slope	Line-Up	Range	Pitch Attitude	Angle of Bank	Rate of Descent	Drift Rate	Angle of Attack	Power	Situational Variables (Critical)
(1)	YOU'RE A LITTLE LOW	-1>-1/2		$\geq$IM			NORM		NORM		DAY/NIGHT
(2)	YOU'RE LOW	-1>-1/2		$\geq$IM			HI		ANY	UNDER	
(3)	YOU'RE LOW	<-1*		$\geq$IM			NORM		NORM		
(4)	YOU'RE A LITTLE HIGH	1/2>1		$\geq$IM			NORM		NORM		
(5)	YOU'RE A LITTLE HIGH	1/2>1 1/2		IC>AR			NORM		NORM		IF HIGH WOD, THIS CALL PROBABLY NOT USED
(6)	YOU'RE HIGH	1 1/2> 2	OK	$\geq$IM			NORM		NORM		NIGHT. CALL EARLY
(7)	YOU'RE HIGH	1/2>1 1/2		$\geq$IM			LO				
	YOU'RE GOING HIGH	$\geq$1/2	OK	$\geq$IM	NORM OR HIGH		LO		NORM OR FAST	OVER	

* NOTE: the symbol "<" in this column can be translated as "Lower than," and ">" can be translated as "Higher than."

TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 1 of 10)

	EXPECTED PILOT RESPONSE	LSO STRATEGY, TECHNIQUE OR COMMENTS	RELATED LSO CALLS
(1)	Add power, increase attitude	If no correction in glideslope is perceived within about 3 seconds, "You're low" or "Still low."	From IM $>$ IC either this call or "Little power" may be given. "Don't settle."
(2)	Add power, increase attitude	If no immediate pilot response, "Power" call is likely, especially at night. Pilots fly low pass at night.	"Little power" may be used from IM "Don't settle."
(3)	Add power, increase attitude	If no immediate pilot response, "Power" call is likely, especially at night. Pilots fly low pass at night.	"Pick it up" - "Put it in the center" "Center the ball."
(4)	Slight power reduction, increase rate of descent	1) Some LSOs will not use "High" calls IM - AR due to possible overcorrection to ramp strike. 2) If no response to this call, "You're high" or "Still high." 3) If line up is bad, LSO will call it first, then work off the Hi, when range is $\geq$ IM. 4) If slow, LSO will not call a high. 5) Use of this call IC - AR is rare. LSO must trust pilot not to overcorrect.	If rate of descent is too low "Don't climb" or "Don't go high." Other calls: "Start it down," "Ease it down."
(5)	Momentary Power Reduction		"Don't go high," "Fly the ball," "Fly it down," "Start it down," "Ease it down," "Don't climb."
(6)	Power reduction, increase rate of descent	LSO prepares "Power" call in case of excess power reduction, especially IM. May use "Little high" if large WOD.	"Start it down," "You're working high," "Center the ball."
(7)	Power reduction, increase rate of descent	This is an uncommon call.	"Don't go high," "You're high."

TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 2 of 10)

Informative LSO Calls	Glide-slope	Line-Up	Range	Pitch Attitude	Angle of Bank	Rate of Descent	Drift Rate	Angle of Attack	Power	Situational Variables (Critical)
(8) YOU'RE GOING LOW	$\leq$-1/2		$\geq$IM	NORM OR LOW		HI		NORM OR OR SLOW	UNDER	
(9) YOU'RE LINED UP LEFT	±1/2	LEFT	$\geq$IM		NORM	NORM	NONE OR LEFT	NORM OR FAST		
(10) YOU'RE LINED UP RIGHT	±1/2	RIGHT	$\geq$IM		NORM	NORM	NONE OR RIGHT	NORM OR FAST		
(11) YOU'RE DRIFTING LEFT	±1/2	OK OR LEFT	$\geq$IM		NORM OR LEFT	NORM	LEFT	NORM OR FAST		
(12) YOU'RE DRIFTING RIGHT	±1/2	OK OR RIGHT	$\geq$IM		NORM OR RIGHT	NORM	RIGHT	NORM OR FAST		
(13) YOU'RE FAST	0>1/2		$\geq$IM	LO				FAST FOR ≈ 3 SEC	OVER	
(14) YOU'RE SLOW	±1/2		$\geq$IM	HI		OK		SLO (4-6 KTS SLO)	UNDER	PITCHING DECK NIGHT
(15) ROGER BALL			X							NIGHT/DAY CCA, NORDO, ZIPLIP

TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 2 of 10)

	EXPECTED PILOT RESPONSE	LSO STRATEGY, TECHNIQUE OR COMMENTS	RELATED LSO CALLS
(8)	Add power, stop rate of descent	Uncommon call.	"You're a little low," "Don't settle," "Don't go low," "Starting to settle."
(9)	AOB to right, establish left to right correction/counter-correction	Uncommon call. Watch for settle on all line up corrections.	"Check your line up," "Start it back to the right" and see "Paddles contact."
(10)	AOB to left, establish left to right correction/counter-correction	Uncommon call. Watch for settle on all line up corrections.	"Check your line up," "Start it back to the right" and see "Paddles contact."
(11)	AOB to right, counter correction to proper line up	Very uncommon call. Watch for settle on all line up corrections.	"Check your line up," "Left for line up."
(12)	AOB to left, counter correction to proper line up	Very uncommon call. Watch for settle on all line up corrections.	"Check your line up," "Right for line up."
(13)	Increase nose attitude, slight power reduction	Not as common as "Slow" call. Will probably not use this call I.C. due to possible overcorrection on A-7, if LSO sees tail light - very fast. LSO perceptual cue is attitude in day. At night it is the indexer lights and their relation to wing tip lights.	"Little fast," "Work it on speed," "Little attitude" (only if manual pass)
(14)	Add power, slight decrease in attitude	LSO will call quickly at night and with pitching deck. May call <u>before</u> indexer light goes green. <u>Slow is</u> predictive of a settle. Will use power calls IC > AR (1 unit AOA).	"You're decelling," "Don't decel."
(15)	None	This is LSO response to pilot transmission acknowledging ball acquisition. LSO control, radios work. Manual assumed (for most aircraft).	See paddles contact. In zip lip, LSO flashes "Cut" lights for "Roger Ball." If pilot calls "Clara" LSO will "talk" him into position to acquire ball.

TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 3 of 10)

Informative LSO Calls	Glide-slope	Line-Up	Range	Pitch Attitude	Angle of Bank	Rate of Descent	Drift Rate	Angle of Attack	Power	Situational Variables (Critical)
(16) ROGER BALL AUTO		X								NIGHT/DAY CCA, NORDO, ZIPLIP
(17) PADDLES CONTACT	±2 or more	>4 wing spans at 1 mile	>X							WEATHER CASE III
P R E C A U T I O N A R Y L S O C A L L S										
(18) CHECK YOUR LINE UP	-1/2>+1	LEFT	≥IM		NORM	NORM	NONE OR LEFT			DAY/NIGHT SHIPS TURN
(19) CHECK YOUR LINE UP	-1/2>+1	OK	≥IM		LEFT	NORM	LEFT			CCA LAST CALL
(20) CHECK YOUR LINE UP	-1/2>+1	RIGHT	≥IM		NORM	NORM	NONE OR RIGHT			CCA LAST CALL
(21) CHECK YOUR LINE UP	-1/2>+1	OK	≥IM		RIGHT	NORM	RIGHT			CCA LAST CALL
(22) DON'T SETTLE (DON'T GO LOW)	±1/2		>IM	NORM OR HIGH		HI		SLO	UNDER	DAY/NIGHT
(23) DON'T SETTLE (DON'T GO LOW)	±1/2		>IM	LO		HI		OK	UNDER	

TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 3 of 10)

	EXPECTED PILOT RESPONSE	LSO STRATEGY, TECHNIQUE OR COMMENTS	RELATED LSO CALLS
(16)		LSO acknowledges auto (APC) approach. Any calls for "Little power" will be given as "Little attitude."	
(17)	Respond to LSO directions	LSO uses this call to assume control of the approach from CCA in an attempt to salvage a bad start. CATCC controller does not transmit after LSO gives this call. Range of occurrence normally 1 1/2 › 3/4 mile.	
(18)	Correct line up in appropriate direction	Same deviation IC will usually get imperative call telling pilot which way to go. But some LSOs use "Check your line up" through IC.	"Right for line up."
(19)	Correct line up in appropriate direction		"Check your line up is more common than "You're lined up left (right)."
(20)	Correct line up in appropriate direction	Left drift is common due to angle deck moving to the right from A/C perspective and relative wind is usually right-to-left.	
(21)	Correct line up in appropriate direction		"Work on your line up."
(22)	Add power to decrease rate of descent	This is an important LSO perceptual skill--to detect a settle before A/C goes low coming down from a high with nose down and underpowered can lead to settle, dangerous if IC.	"Don't settle" is more common than "Don't go low." "Don't go through it" used if coming down from a high. "Don't decel."
(23)			"Little power," "You're going low," "Don't go through it."

TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 4 of 10)

Informative LSO Calls	Glide-slope	Line-Up	Range	Pitch Attitude	Angle of Bank	Rate of Descent	Drift Rate	Angle of Attack	Power	Situational Variables (Critical)
(24) DON'T CLIMB (DON'T GO HIGH)	+1/2>1 1/2		AR			LO		OK OR FAST	OVER (aural cues)	PITCHING DECK WOD EXPERIENCED PILOT
(25) DON'T GO HIGH	-1/2>1 1/2		>IM			LO		OK OR FAST	OVER	
(26) KEEP YOUR NOSE UP (HOLD YOUR ATTITUDE)	(THE LSOs INTERVIEWED SAID THEY NEVER USE THESE CALLS. SEE IMPERATIVE CALLS "ATTITUDE" OR "A LITTLE ATTITUDE")									
(27) HOLD WHAT YOU'VE GOT	±1/2	OK	X>TD	NORM OR VARYING	NORM	NORM	NONE	OK	NORM	PITCHING DECK
IMPERATIVE LSO CALLS										
(28) A LITTLE POWER (manual)	-1>-1/2		<IM			NORM		NORM	NORM	NIGHT = SOONER
(29) A LITTLE POWER (manual)	±1/2		<IM	Δ to LO		HI		NORM	NORM OR UNDER	BURBLE LINE UP Δ
(30) A LITTLE POWER (manual)	±1/2		<IM	Δ to LO		NORM		SLO	UNDER	NOISE ON DECK
(31) A LITTLE POWER (manual)	≤1		≥IM			NORM		SLO	UNDER	

TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 4 of 10)

EXPECTED PILOT RESPONSE	LSO STRATEGY, TECHNIQUE OR COMMENTS	RELATED LSO CALLS
(24) Reduce power, probably dip nose down then up	If LSO hears too much power coming on, an attempt to avoid a bolter can be a dangerous call if given IC and if pilot overcorrects--reduce too much power > ramp strike, or hard landing.	"Fly it down," "Fly the ball," "You're a little fast" (a sneaky call), "Don't go high," "Ease it down."
(25) Reduce power, establish proper rate of descent	When overcorrecting from a low.	"Don't climb," rarely used in this case, also "Don't go through it," "Don't climb through it."
(26)		"Attitude," "Don't drop your nose," "Hold it up," "You're decelling," "You're slow."
(27) Maintain current rate of descent and temporarily ignore the ball.	To prevent "chasing" the ball in pitching deck (X > IC). To prevent "deck spotting" or making a "lunge" (AR > OW) (LSO must know pilot tendencies.)	"Hold it up there," "Deck's down," "Don't chase it," "Don't chase the ball," "Hold your line up," "Deck rolling."
(28) Add a little power immediately (~ 400-500 LB/HR in A-7)	A frequent call. Manual mode only. Used when a low is not being corrected.	"A little attitude" if in auto (APC) "A little power."
(29)	When GS is OK, but rate of descent is excessive.	"Power" will soon follow if correction is insufficient.
(30)		At IM > IC position, some LSOs may use informative calls, "Little low," "Don't settle," "Don't decel," "You're slow."
(31)	When low and slow, LSO will use power calls farther out, rather than informative calls.	

TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 5 of 10)

Informative LSO Calls	Glide-slope	Line-Up	Range	Pitch Attitude	Angle of Bank	Rate of Descent	Drift Rate	Angle of Attack	Power	Situational Variables (Critical)
(32) A LITTLE POWER	<-1		≥IM			NORM		NORM		2nd CALL
(33) A LITTLE POWER	±1/2	LEFT	<IM	Δ to LO		PREDICT Δ to HI				
(34) POWER (manual)	IF THE CALL "LITTLE POWER" DOES NOT ELICIT A SUFFICIENT RESPONSE, "POWER" WILL SOON FOLLOW (~ 1-5 sec).									
(35) POWER (manual)	-1/2>-1		<IM			HI		NORM	UNDER	WOD
(36) POWER (manual)	<-1		<IM			NORM		NORM	NORM	
(37) POWER (manual)	<-1/2		<IM			NORM		SLO	UNDER	
(38) POWER! (manual or auto)	<0		IM>IC			VERY HI		SLO	UNDER	COME DOWN FROM HIGH
(39) POWER! (manual or auto)		IF A PREVIOUS POWER CALL (ATTITUDE IF AUTO) RECEIVED INSUFFICIENT RESPONSE (CALLS SPACED ~ 2-5 SECONDS APART).								
(40) POWER	ANY		AR>OW			HI				TO AVOID HARD LANDING
(41) POWER	ANY		AR			ANY				TO ENSURE ADEQUATE HOOK TO RAMP CLEARANCE
(42) POWER	<-1		X>IM			HI		SLO	UNDER	

TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 5 of 10)

EXPECTED PILOT RESPONSE	LSO STRATEGY, TECHNIQUE OR COMMENTS	RELATED LSO CALLS
(32) If failure to add power after "You're low," or similar call	When "Low" call is not responded to within ~ 2 seconds, anywhere in approach.	At IM > IC position, some LSOs may use informative calls, "Little low," "You're slow," "Don't settle," "Don't decel."
(33) Power then line up correction	Call "Little power--right for line up" to avoid settle on LU correction.	
(34)		Wave-off (if "Power" response insufficient) "Attitude" (if auto).
(35) Add considerable power immediately	Power > high rate of descent coming from a "High."	"Little power," "Don't settle," "Don't decel."
(36) Add considerable power immediately	Uncorrected low ball.	"Don't go low," "Don't go through it" (from HI).
(37) Add considerable power immediately	Low and slow.	
(38) Add power (and break-out of auto)	"Hard" power call > Low, Slow, High Rate Descent IM.	
(39) Pilot expected to be at military power (~ 9000 LB/HR in A-7) (Squadron doctrine, not Navy-wide.)	A good and proper call occasionally causes a bolter.	"Power" call also requires pilot to break out of auto to manual.
(40)		
(41)		
(42)		

TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 6 of 10)

Informative LSO Calls	Glide-slope	Line-Up	Range	Pitch Attitude	Angle of Bank	Rate of Descent	Drift Rate	Angle of Attack	Power	Situational Variables (Critical)
(43) GO MANUAL (auto)	IF ROUGH GS CONTROL		>IM	EXAMPLE: Δ to HI				SLO OR FAST	NO Δ POWER	OVER 35 KTS WOD
(44) A LITTLE ATTITUDE	±1/2		<IM	LO	NORM	NORM OR HIGH		FAST	OVER OR NORM	
(45) A LITTLE ATTITUDE (auto)		SAME AS FOR "A LITTLE POWER."								AUTO
(46) ATTITUDE	ANY		AR(OW)	LO						
(47) ATTITUDE	-1/2>1/2		<IM	LO	NORM	NORM		FAST	OVER	
(48) ATTITUDE (auto)		SAME AS FOR "POWER," IN MANUAL (BUT NOT "POWER!").								
(49) RIGHT FOR LINE UP	-1/2>1	LEFT	<IM			NORM	NONE	NORM OR FAST		SHIPS TURN BURBLE. (Causes left drift on some ships.)
(50) RIGHT FOR LINE UP	-1/2>1	NORM OR RIGHT	<IM			NORM	HIGH RATE LEFT	NORM OR FAST		

TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 6 of 10)

EXPECTED PILOT RESPONSE	LSO STRATEGY, TECHNIQUE OR COMMENTS	RELATED LSO CALLS
(43) Select "Manual" mode (Breakout of APC)	This rare call is used when LSO wants a manual rather than APC approach: high winds, rough auto bolter, or APC malfunction.	
(44) Increase nose attitude slightly and immediately	IM, LSO may call this to trade low/fast for on GS, on-speed. AR > OW to prevent landing on nose wheel.	"Attitude," "You're fast."
(45) Increase nose attitude also gives increased power, automatically	LSO replaces the call "Little power" with "Little attitude" on an auto pass. If LSO calls "Power" rather than "Attitude," pilot should break out of auto.	"A little power."
(46) Increase nose attitude	To prevent 3-point landing (on nosegear).	
(47) Increase nose attitude immediately	Same as "Little attitude" but encouraging a quicker, or greater magnitude pilot response.	"Little attitude," "You're fast," "Get it up," "Hold it up," "Don't drop your nose."
(48) Increased nose attitude gives auto-increase in power	LSO gives "Attitude" call to mean "Power" in an auto approach. If dangerous, LSO will give "Power"--requiring pilot to breakout of auto.	"Power."
(49) AOB to right then wings level on centerline, to correct line up	Right for line up is a common call due to angle deck movement. Easy for LSO to see correction in LU (AOB IC).	"Check your line up," (usually used > IM "Come right for line up," "Power - Right for LU." "Bring it back to the right."
(50) Same as above, to stop drift rate	Right for line up is a common call due to angle deck movement. Easy for LSO to see correction in LU (AOB IC).	~ 98 percent are "Right."

TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 7 of 10)

Informative LSO Calls	Glide-slope	Line-Up	Range	Pitch Attitude	Angle of Bank	Rate of Descent	Drift Rate	Angle of Attack	Power	Situational Variables (Critical)
(51) LEFT FOR LINE UP	-1/2>1	RIGHT	<IM			NORM	NONE	NORM	NORM	
(52) BOLTER	.A									Δ MAX (MILITARY)
(53) UNCOUPLE	ROUGH GS IF IN ACLS		>IM							
(54) CUT (CALL)										
(55) CUT LIGHTS (LSO MANUAL ACTION)										ZIPLIP
(56) DROP YOUR HOOK										
(57) DROP GEAR										NO LIGHTS
(58) DROP YOUR FLAPS										
(59) WAVEOFF*	<-2		IM>IC			LO				"TRICK OR TREAT"
(59A)	<-2		X>IM			NORM OR HIGH		NORM		DAY/NIGHT PITCHING DECK

* SEE "POWER" ALL THE SAME PARAMETERS WILL ELICIT A WAVE-OFF, IF NO (OR INSUFFICIENT) RESPONSE TO "POWER."

TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 7 of 10)

	EXPECTED PILOT RESPONSE	LSO STRATEGY, TECHNIQUE OR COMMENTS	RELATED LSO CALLS
(51)	AOB to left, then wings level	Some LSOs will not use this call for fear of left drift on TD, causing A/C to go over the side. They W/O instead.	~ 2Δ are "Left." "Come left," Wave-off" are related calls.
(52)	Pilot should already be at military, and should increase pitch attitude to optimum	LSO always gives this call when an A/C fails to hook a wire: long or hookskip.	"Power!" "Attitude," "Bolter bolter."
(53)	Transition from ACLS approach to pilot-controller approach	A rare call. Pilot usually uncouples early on his own. Used if LSO sees rough GS in ACLS mode I.	"Wave-off" if IC.
(54)		This call is not used for jets, except barricade arrestments. Cut lights are given by LSO in conjunction with this call. It means "Cut power" for props.	
(55)		Cut lights means "Power" in ziplip/EMCON.	
(56) (57) (58)	Drop hook Drop gear Drop flaps	LSO Hook-Spotter, enlisted man on LSO platform, checks each aircraft for A/C type, gear, hook, flaps down, clear or foul deck.	Usually "Hook" (~ 98 percent) (~ 1 percent) (~ 1 percent)
(59)		Too difficult a correction for any range except start.	
(59A)	Full military power immediately assume optimum pitch attitude	"Wave-off" call given simultaneously with manual action wave-off light on lens.	"You're low," "Power."

TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 8 of 10)

Informative LSO Calls	Glide-slope	Line-Up	Range	Pitch Attitude	Angle of Bank	Rate of Descent	Drift Rate	Angle of Attack	Power	Situational Variables (Critical)
(59B)	<-1/2		IM>IC			HI		SLO	UNDER	WOD LOW FUEL STATE NO BINGO NO TANKER
(59C)	-1		<IM	NORM		NORM		NORM	NORM	(+ NO RESPONSE TO "POWER" CALLS)
(59D) WAVEOFF*	ANY		≤IM			VERY HI		NORM OR SLO	ANY	
(59E)	-1	LEFT	IC>W/O MIN			NORM	LEFT			
(59F)	-1>1 1/2	RIGHT	IC>W/O MIN			NORM	RIGHT			
(59G)	<-1		IC>W/O MIN	LO		HI		SLO	UNDER	WOD, PITCHING DECK
(59H)	0>+	>25' LEFT >20' RIGHT	W/O MIN		NORM	NONE				BOARDING RATE
(59I)	>+2		IM>			NORM		NORM	NORM	
(59J)	≥+1 1/2		IC>AR			LO		FAST	OVER	
(59K) (ACLS PASS)	ROUGH GS		IC			VARIABLE		VARIABLE	VARIABLE	

*SEE "POWER" ALL THE SAME PARAMETERS WILL ELICIT A WAVE-OFF, IF NO (OR INSUFFICIENT) RESPONSE TO "POWER."

TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 8 of 10)

EXPECTED PILOT RESPONSE	LSO STRATEGY, TECHNIQUE OR COMMENTS	RELATED LSO CALLS
(59B)		
(59C)	LSO uses wave-off to preserve safety of flight whenever an approach deteriorates to the point that the probability of the pilot's making successful corrections becomes unacceptably low.	"You're slow," "Power."
(59D) +LSO judges A/C is in danger of contacting ramp	LSO often gives Wave-off after seeing insufficient pilot A/C response to "Power" call(s).	
(59E)	Trends are critical to wave-off decision--more important than position.	
(59F)	LSO may risk IFE by giving impossible wave-off to avoid ramp strike.	
(59G)	LSO is judging acceptability of hook-to-ramp clearance and terminal sink rate (hard landing); if he predicts unacceptable > wave-off.	

TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 9 of 10)

Informative LSO Calls	Glide-slope	Line-Up	Range	Pitch Attitude	Angle of Bank	Rate of Descent	Drift Rate	Angle of Attack	Power	Situational Variables (Critical)
(59L)	≤-1		IC>W/O MIN	NORM		NORM		NORM	NORM	PITCHING DECK COMING UP (~ 10 FT) TO COINCIDE WITH A/C CROSSING RAMP WITH PITCHING DECK COMING UP.
(59M)	±1/2		W/O MIN			HI		SLO	UNDER	
(59N)	ANY	±100 FT	IM (OR ~ 4° OFF CENTERLINE NO. 3 WIRE ORIGIN FROM IM > IC)							
(59O)	<-1 1/2		X>IM			HI		SLO	UNDER	
(59P)	>+1 1/2	LEFT OR RIGHT	≤IC> W/O MIN							
(59Q)	>+1 1/2		IC	NOT NORM			HI		SLO	UNDER
(59R)	≥-1	15 LEFT 10 RIGHT	W/O MIN			NORM	NOT COR-RECTING			
(59S)	>+2		X >			LO				

TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 9 of 10)

EXPECTED PILOT RESPONSE	LSO STRATEGY, TECHNIQUE OR COMMENTS	RELATED LSO CALLS

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TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 10 of 10)

Informative LSO Calls	Glide-slope	Line-Up	Range	Pitch Attitude	Angle of Bank	Rate of Descent	Drift Rate	Angle of Attack	Power	Situational Variables (Critical)
(59T)	>+1 1/2		IM>AR			NORM OR LO			OVER	If 2 "YOU'RE HIGH" CALLS HAVE BEEN GIVEN AND PILOT RES-PONSE (POWER REDUCTION) HAS BEEN INSUFFICIENT (SINK RATE NOT HIGH).
(59U)	ANY		W/O MIN					VERY FAST		
	THIS LIST OF WAVE-OFFS IS NOT EXHAUSTIVE.									
(60) WAVE-OFF, FOUL DECK			IM>W/O MIN							

(NOTE: NO "HIGH" IMPERATIVE CALLS)

TABLE 2. CALL LISTING FORMAT OF LSO MODEL (part 10 of 10)

EXPECTED PILOT RESPONSE	LSO STRATEGY, TECHNIQUE OR COMMENTS	RELATED LSO CALLS

(60) Whenever red foul deck light or LSO Hook-Spotter/Talker indicates foul deck, LSO works approach to see if deck will clear. If not, wave-off given IC > WO/Min or farther out (IM > IC) if no chance for deck to clear (as reported by Asst, LSO). If High, coming down with power off, LSO may give foul deck wave-off IM.

The Call-Listing Format does not portray the sequential dependencies and loops that are depicted in the Flowchart Format. However, the Call-Listing Format may be easier to translate into computer software. Minor differences between the two formats of the model probably exist. These differences are not intentional. They merely reflect the somewhat independent evolution of the two formats.

SITUATIONAL VARIABLES

The term "situational variables" refers to all variables other than aircraft approach dynamics that influence the LSO's task. The following list of situational variables was developed through interviews with LSOs and cannot be assumed to be exhaustive. The exact influence of changes in these variables on the LSO's task is unknown. In many cases, it can be assumed that the basic LSO decision-making processes remain the same, but the criteria for an acceptable approach change. In other cases, such as reduced visibility, the LSO must operate with diminished perceptual cues, hampering his ability to predict the immediate future state of aircraft.

The situational variables will be listed by category.

A. Aircraft Variables
  1. Aircraft type
  2. Configuration (gear, hook, flaps down)
  3. Manual or auto throttle
  4. Emergency or unusual status
     a. Radio failure (NORDO)
     b. System/subsystem failure or malfunction
     c. Hung ordnance
     d. No angle of attack indicator
     e. Lighting configuration abnormality
        1) No wing lights
        2) No approach lights
        3) Approach index lights installed incorrectly
     f. Battle damage
  5. Gross weight
  6. Fuel state

B. Environment/Visibility Variables (weather)
  1. Day/night
  2. Horizon (clouds, fog, etc.)
  3. Sun location
  4. Ship's motion
     a. Pitching deck
     b. Rolling deck
     c. Predictability
  5. Destroyer position
  6. Rain or other precipitation
  7. Wind direction and speed (wind over deck, WOD)
  8. Ship induced air wake turbulence (burble)

9. Use of MOVLAS due to pitching deck
10. Ship blows tubes (stack gas)
11. Aircraft noise on deck

C. Carrier Variables
 1. Carrier class
 2. Ramp to No. 1 wire distance
 3. Ramp to LSO platform distance
 4. Centerline to LSO platform distance
 5. Ramp to touchdown distance
 6. LSO platform to touchdown distance
 7. Hook to ramp distance (ideal)
 8. Type of LSO platform--flush deck/recessed deck (West coast/East Coast)
 9. LSO equipments
    a. Head-Up Display (LSO-HUD) installed
    b. LSO equipment chronic malfunction
 10. CLASS system (heave stabilization)
 11. 3 1/2 or 4 degree glideslope
 12. Ship's trim
 13. Pendants removed

D. Pilot Variables
 1. Experience
    a. Total
    b. In-type
    c. Recent carrier
 2. Personal tendencies and trends on carrier approach
 3. Vertigo
 4. Physiological or psychological disorders

E. Operational Variables
 1. Running out of sea room
 2. No bingo field available
 3. Deteriorating weather
 4. Captain or Air Boss pressure for boarding rate
 5. ZIP LIP or EMCON
 6. Type of operations--CQ, Fleet, War
 7. Ship's turn
 8. Tanker availability
 9. Foul deck

PERFORMANCE MEASUREMENT

Information obtained in the LSO task analysis can be applied to the identification of candidate performance measures for LSO-trainees. The ultimate criterion of the validity of training performance measures should be performance in the fleet. Since this type of criterion is not presently available, the recommended strategy is to consider a wide variety of candidate performance measures. These can be selectively eliminated through subsequent research comparing the performance of highly qualified LSOs with the performance of trainees. Certain knowledge requirements exist for successful performance of the LSO task, and they may be evaluated by paper and pencil test. However, the objective here is to identify the functional aspects of the LSO's waving task that are available for the measurement of individual differences in performance.

The following list of candidate LSO trainee performance measures was developed from the LSO interviews and observation.

A. Waving Behavioral Measures
   1. Verbal--LSO calls
      a. Correct call given at correct time
      b. Late call
      c. Early call
      d. Incorrect/Inappropriate call
      e. Unnecessary call
      f. Number of calls per approach
   2. Wave-off (manual action and call)
      a. Correct acceptance (no wave-off)
      b. Failure to wave-off
      c. Late wave-off
      d. Early (unnecessary wave-off)
      e. Correct wave-off
   3. Cut lights (manual action)
      a. Use at correct time
      b. Late cut lights
      c. Early cut lights
      d. Failure to use cut lights

B. LSO "Grading" Task
   1. Correct description/reconstruction of the approach
   2. Failure to downgrade an approach deviation
   3. False detection of an approach deviation

C. System Operational Measures (confounded with pilot performance and other variables)
   1. Boarding rate
   2. Bolter rate
   3. Wire frequency
   4. Wave-off rate
   5. Accident rate
   6. Off-center landings

D. Synthetic Measures (trainer only)
   1. Perception, recognition, identification of glideslope and line-up position deviations (stopped action, slow motion, or real-time)
   2. Perception and prediction of pending deviations (stopped action)
   3. Identification of minimum wave-off point

E. Other measures
   1. Supervisor ratings (CAG LSO or instructor LSO)
   2. Critical Incident Technique--performance in a critical situation indicative of a gross error or exceptional skill

As reflected in the LSO Flowchart Model, calls and wave-offs comprise nearly the entire output of the LSO during a carrier approach. These categories will undoubtedly prove to be the most fertile ground for developing LSO trainee performance measures. Advancements of technology in computer speech understanding appear to provide a feasible method for the measurement of verbal performance based on a limited vocabulary size such as LSO calls.

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